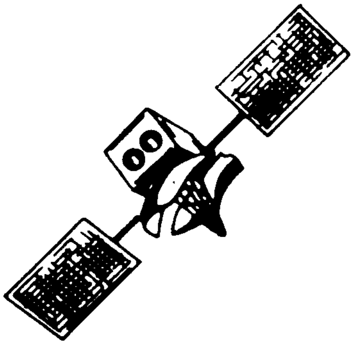


The New HOWARD TERMINAL MANUAL

UPDATED, 1981 VERSION of the STT Manual that has shown thousands how to build their own low-cost, state-of-the-art 24 channel satellite television receiver (plus bi-polar builder-special LNA).

Copyright 1981 by:
Satellite Television Technology
P. O. Box G
Arcadia, OK 73007
and Taylor Howard

PRICE: $30 per copy

THE 'NEW' HOWARD TERMINAL MANUAL

PERHAPS 5,000 people purchased the original Howard Terminal Manual, first brought out in mid-1979. Thousands of home-built satellite receivers have been built from that Manual. NOW Taylor Howard updates his most-popular-of-all Satellite Manuals with the assistance of special circuit boards offering greater ease of construction for the home-builder enthusiast.

TOPIC PAGE NUMBER

A BRAVE New World 2
THE Receiving System 6
THE Horn Antenna 8
THE LNA (Low Noise Amplifier) 9
THE Receiver 13
DUAL Conversion Board 13
200 MHz Low Pass Filter 17
70 MHz Intermediate Frequency Board 17
THE Demodulator Board 20
SINGLE/Dual Audio Cards 24
DC CONTROL And Metering 26
REMODULATING To RF 28
PLOTTING System Performance 29
CONSULTING Service From Professor Howard 31

THE COVER - Taylor Howard, Professor at Stanford University, President of the Society of Private And Commercial Earth terminals (SPACE), one of the very first people in the world to have a private home satellite terminal and certainly the first to create from scratch a complete receiver system design which thousands could duplicate on their own. The low-cost home-earth-terminal industry's "Man Of The Year" for 1980. Back again with an updated Manual from STT.

THIS MANUAL has been produced and is being distributed by Satellite Television Technology, with editorial offices located at Grace Bay, Providenciales, Turks & Caicos Islands (find **that** on your map!) in the West Indies. **Business offices** are located at (**STT**), P. O. Box G, Arcadia, Oklahoma 73007 (405/396-2574). You may call Rick Schneringer there.

COPY THIS MANUAL - Professor Taylor Howard wrote this manual on his home computer word processing system. **If** he wanted to distribute low-cost copies he would merely program the computer system to spit out copies all day long. It is his wish that low-cost second generation copies not be made. Towards that end we are registering this publication with the U.S. Copyright Office and placing you on notice here that any copies made are a violation of federal copyright law. **Entire contents**, in whole and in part, **Copyright 1981** (© 1981) by Satellite Television Technology (STT) and by H. Taylor Howard.

CONTACTING STT - You have purchased this Manual because you wish to learn all of the nitty-gritty facts about building your own private (as in backyard) satellite earth terminal (TVRO). We welcome you to the clan. Numerous other **STT** Manuals fill in some of the voids left here; such as antenna construction (**Nelson Parabolic Antenna Manual**), antenna system mounts and satellite locating (**Gibson Satellite Navigator**), and how those funny little boxes of electronics operate and what (and where) you look for hidden away in their vast spectrums (**Coop's Satellite Operations Manual**). We invite you to inquire (as in call or write) how these nifty Manuals can make you a new man (or woman; as the case may be). We also invite you to ask about **CSD** (**Coop's Satellite Digest**), the one, single monthly worldwide authoritative source for data on all that is happening today in low-cost satellite terminals and satellite operations.

HOWARD TERMINAL CIRCUIT BOARDS - If you are setting out to build some or all of the Howard Terminal Receiver described in these pages there is only one source for these circuit boards. Surprise. It is not H. Taylor Howard. "Genuine" PC cards for the receiver described here are available exclusively from: **Robert M. Coleman, Route 3, Box 58-A, Travelers Rest, S.C. 29690**. A complete set of boards (Dual Conversion, 70 MHz IF and Filter, Demodulator, Single Channel Audio and AFC/DC Control/Metering) is priced at $99 (US funds only); included is a list of distributors stocking those parts not common at Radio Shack.

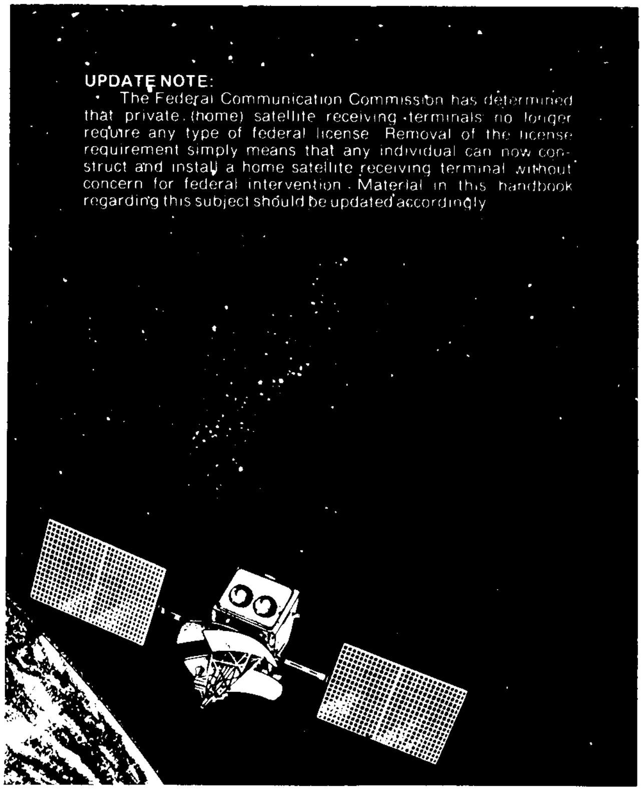
A BRAVE NEW WORLD

The purpose of this Manual is to provide the serious satellite enthusiast with the knowledge necessary to construct a home satellite television receiving system. Emphasis in this Manual is placed on the receiver and a bi-polar low noise amplifier but with enough discussion of the remaining system elements to enable the first time builder to make intelligent choices about antennas, amplifiers and the balance of the system.

In 1978 the author undertook the design and fabrication of a satellite television receiver which was to open the door to an entire industry. At that time all TVRO receiving systems utilized relatively expensive receivers costing upwards of $5,000. The receivers then available had originated as INTELSAT grade video receivers, designed to exacting commercial standards, where price was secondary to 100% performance 100% of the time.

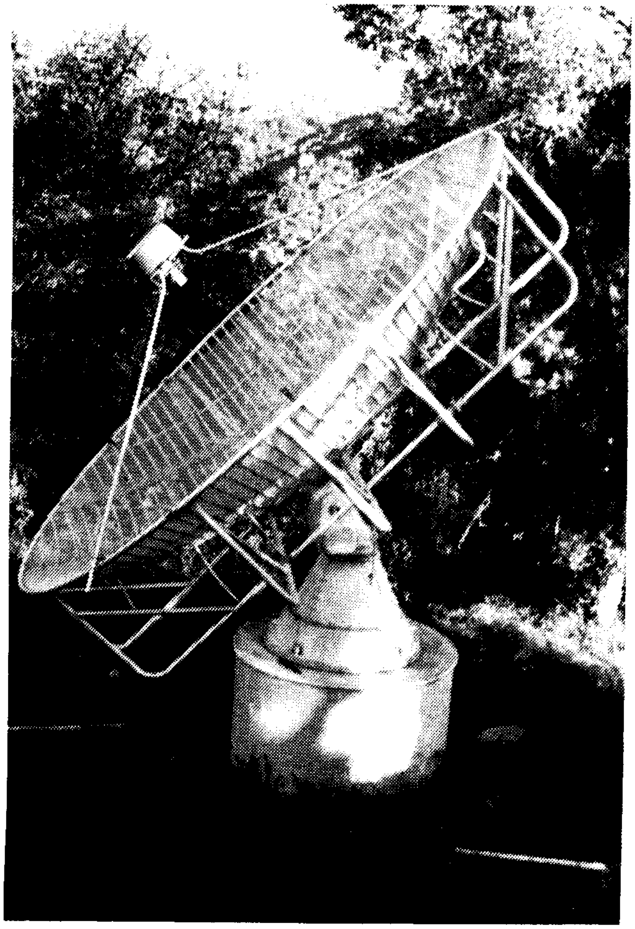
Having installed my own satellite terminal in 1976, and having worked with both surplus (i.e. converted) equipment as well as various commercial units then available, it became apparent that while virtually anyone reasonably handy with tools could fabricate a suitable receiving antenna, and duplicate with reasonable precision the bi-polar versions of the low noise amplifiers, the receiver remained a stumbling block for most would-be-satellite enthusiasts. Clearly some re-direction was required to bring the cost of the receiver technology plus the complexity of the receiver technology 'down' to a level which less professional people could duplicate.

Through Satellite Television Technology, in the summer of 1979, the first **Howard Terminal Manual** was released. More than 5,000 Manuals later it is clear that our initial designs have been followed and improved upon by others. The first **Howard Terminal Manual** described a basic double conversion receiver which offered good operational characteristics, reasonable ease of construction (a function of your own background) and good price sensitivity. From the first Manual and the thousands of receivers created from that Manual has come a large amount of helpful feedback which is reflected in this **New Howard Terminal Manual**.



UPDATE NOTE:

- The Federal Communication Commission has determined that private (home) satellite receiving terminals no longer require any type of federal license. Removal of the license requirement simply means that any individual can now construct and install a home satellite receiving terminal without concern for federal intervention. Material in this handbook regarding this subject should be updated accordingly.



The advances in the satellite field come almost daily and it is good to question whether a receiver originally created on breadboards in 1978, reduced to duplicable designs in 1979, is behind the times in 1981.

In truth the original receiver is more modified than changed in its 1981 format. Anyone with the original Manual in hand is well equipped, even today, to create a TVRO receiver with good performance. But there have been improvements and more important than changes in performance and design are those changes which have evolved to make the duplication a relatively easy project.

Perhaps the most significant change from the original Manual has been the design by the author and collegue Robert Coleman of a complete set of circuit boards for the builder of this sytem. Whereas the original receiver utilized proto-type board materials requiring point-to-point wiring and other time consuming processes, the **New Howard Terminal Manual** relates a 1981 version of the same basic unit which is now fully backed up by the ready availability of carefully designed and field proven circuit boards. This factor alone can and should reduce by a factor of two or better the actual time spent in the fabrication of the receiver described here.

The growth of private (home) satellite television receiving terminals since the introduction of the original Manual at SPTS '79 in Oklahoma, in mid-1979, has been fascinating to watch and to participate in. At that point in time virtually every enthusiast attending SPTS was there with an electronics background. This put most of the enthusiasts on about the same level of interest and when they talked shop most of the participants had an understanding of everything being discussed. In the subsequent growth of this young industry many tens of thousands of new enthusiasts have come into the field with very little or even no electronics background. Many of these 'new comers' little realize that microwave electronics technology is **supposed to be** one of the more complex and complicated areas of electronics. If one were to survey the salaries paid to all electronic design engineers or field engineers, one would quickly see the 'premium' paid for knowledge in this field. In a sense, even within electronics, microwave frequency range technology is considered to be something of a 'black magic art'.

Is microwave technology really that complicated? Perhaps not. Many university courses taught in this area concentrate on classic microwave plumbing and on printed circuit technology. The fact is that as materials have improved microwave electronics has become simpler. The microwave portion of the system requires, mainly, attention to mechanical detail and not access to large computers or university level technology.

Is the creation of a satellite home receiving system uncomplicated? No, not at all. **It is** a complex system with very **close** tolerances. Many of the construction and building techniques which suffice at lower frequencies are simply not acceptable at the microwave frequency range. Long lead lengths, massive globs of solder, careless measurement of parts are all reason for concern at microwaves. Again, the semi-professional electronics enthusiast coming into microwave from 'lower frequency' fields may bring with him ingrained bad habits which the neophyte would not have to draw upon.

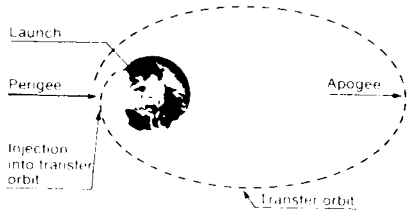
So how do you determine if your own capabilities are such that you should undertake the duplication of this receiver? First of all be honest with yourself. Read this Manual through, carefully, several times. Do you see areas where you simply cannot cope with the information given? There is an out. The author maintains a one-time-fee consulting service (see back of Manual) wherein questions submitted **by mail** (sorry - no telephone queries) will be answered. Secondly, weigh the cost of acquiring the parts (a changing situation but generally in the $500 region) versus acquiring one of the now-available factory built satellite receivers in the $1,000 range. Performance-wise the factory built radios and the receiver described here will be quite comparable. **However** - there is one distinct advantage to having your own home built receiver. That is that because this is such a fluid, evolving technology, if you build your own (and one assumes learn while you build) you will then be in a better position to add new circuits, make changes, and generally keep your receiver up to the state of the changing art as it evolves. Making similar adaptations to a factory built radio may not be as easy simply because you lack an understanding of what each section of it does and how it accomplishes that function.

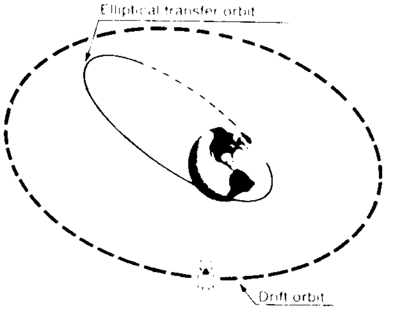
The Satellite System

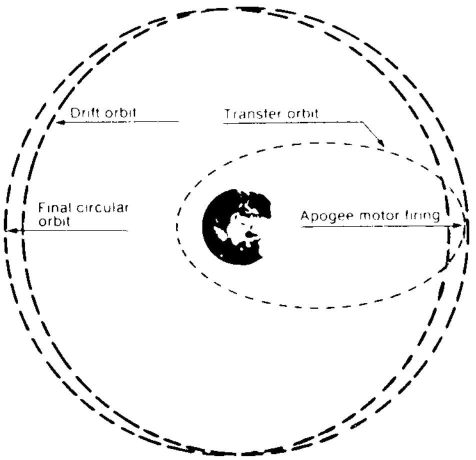
There are a number (more than 35 at this writing) of communication satellites in orbit above the equator around the earth. Most of these satellites have the capacity to carry (as in relay) one or more channels of television. As Arthur C. Clarke postulated in 1945, three such satellites, spread evenly about the earth could provide direct television to more than 99% of all of the human habitants of earth. Simultaneously and in real (i.e. live) time.

Fortunately for you and me these satellites have developed along more or less universal lines. With a few small wrinkles a satellite receiver designed to receive TV transmissions in North America will function in Siberia or Columbia as well. There is a positive side effect of this happenstance; while most of the TV transmissions that will interest you most will originate in North America and be beamed back to North via US or Canadian satellites, it is of some comfort to know that the basic receiver you will be employing is capable of dragging in TV transmissions from Brasil or Moscow or Paris with the same basic technical formats. All of this is simply by way of saying that satellite TV is a very universal service and the capacity is there to tune in the world in your home, "live and direct" from wherever the programs originate.

Geostationary satellites are lifted into a special orbit called 'geo-stationary'. This means they rest directly above the earth's equator, at an altitude of 22,300 miles. This is a 'magic distance' because at this elevation the satellite can be 'locked' into synchronization with the earth itself. As the earth rotates on its axis once each 24 hours the satellite drifts around the earth at the same speed. This means that when you point your satellite antenna into the sky and fix onto a 'bird', once you have found that satellite you can peak your antenna on maximum signal and forget it; the antenna in your yard and the satellite will stay locked up from that point on. This is a very important consideration since the intrigue of satellites would be considerably less if you were required to constantly 'track' a moving satellite across your sky!







The satellites of primary interest to us receive transmissions from ground stations called 'uplinks'. These uplink stations send signals to the satellite in a frequency band near 6,000 megahertz (6 GHz). The received signals are amplified and frequency converted down to a new frequency range between 3.7 and 4.2 GHz. Then these 4 GHz 'range' signals are sent or transmitted back to earth. Within North America (which includes US and Canadian satellites) the 'band' from 3.7 to 4.2 GHz is broken up into descrete 'channels'. The older satellites in orbit, operated by Canada (ANIK series) and Western Union (WESTAR series) have 12 channels each. And each of these 12 channels is capable of

TABLE ONE

Satellite Name	SATCOM FI	SATCOM FIIIR	WESTAR 2	SATCOM F2	ANIK B	WESTAR 1	COMSTAR D2	WESTAR 3
Longitude	135°	132° (*)	123.5°	119°	109°	99°	95°	91°
Total # Channels	24	24 (*)	12	24	12	12	24	12
TV Channels (**)	20	24 (*)	5	5	5	6	12	6
Audio Sub-carriers	6.8	6.8	6.2/6.8	6.8	6.8	6.2/6.8	6.2/6.8	6.2/6.8

* - SATCOM FIIIR due to launch mid 1981, become operational fall 1981. When it becomes operational all previous CATV programming traffic on FI plus some of the CATV program traffic now on COMSTAR D2 will **transfer to** the new FIIIR; the balance of the programming traffic now on D2 will transfer to FI.

*** - Number of TV channel (services) operational varies as a function of time of day and satellite. Number shown is 'average' in first quarter of 1981.

---

carrying a full television image with accompanying audio (sound). The newer satellites, operated by RCA (SATCOM series) and ATT/GTE (COMSTAR series) have 24 channels; each capable of handling a full TV program with audio. RCA and ATT/GTE achieve 24 channels where Canada and Western Union create 12 channels by employing a technique called 'polarization diversity'. This means that whereas WESTAR and ANIK birds transmit 12 channels (each 40 MHz wide and each within the 3.7 to 4.2 GHz spectrum) using a single (horizontal) polarization, SATCOM and COMSTAR birds re-use the same frequency band two times. They transmit one set of 12 channels using horizontal polarization (like the WESTAR and ANIK birds) and then they turn around and "re-use" the same frequency range again by transmitting another 12 channels on the opposite (vertical) polarization.

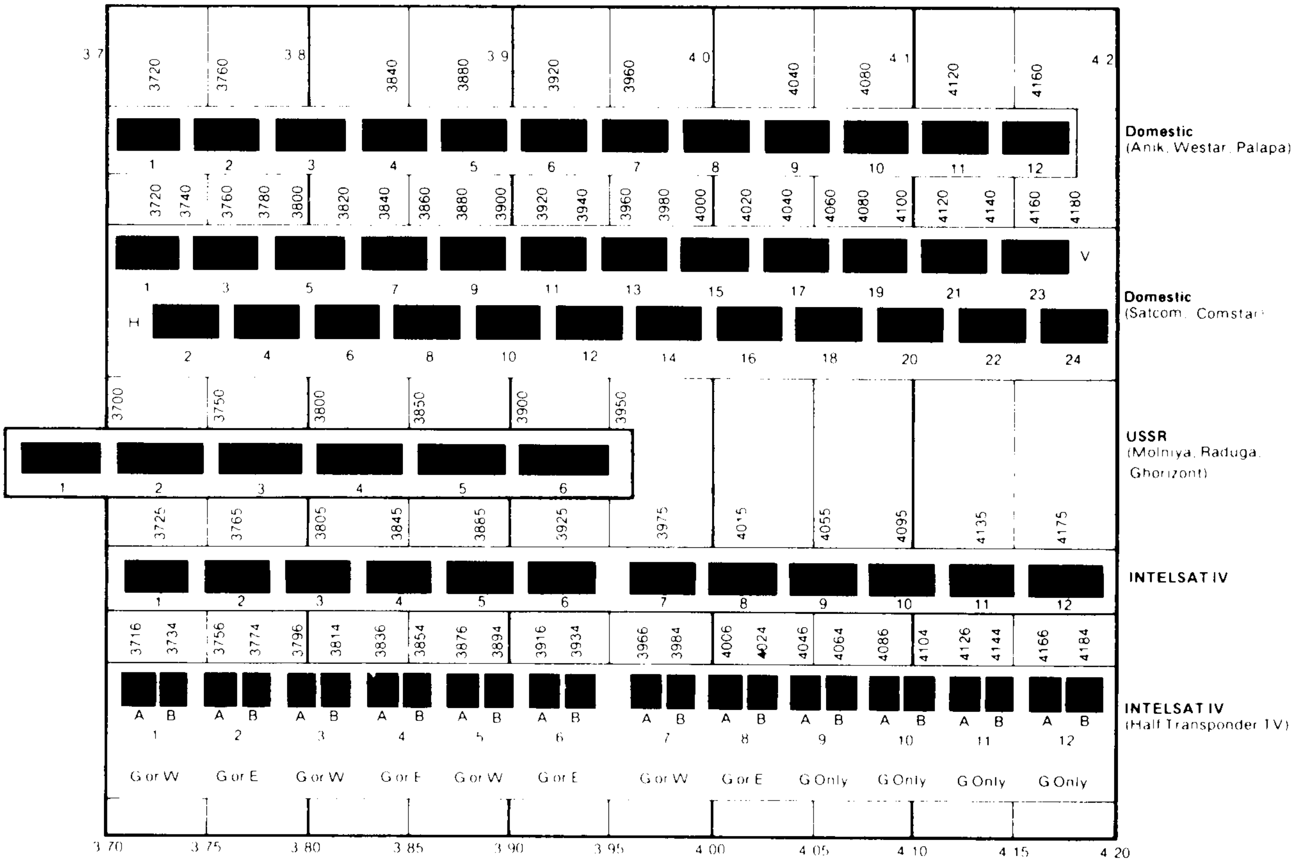
On the ground, at your receiving terminal, you 'separate' the vertical and horizontal polarized signals with a simple 'twist' of your antenna feed horn. In one position or alignment it "sees" the horizontal signals; in another position, rotated on its own axis, the feed horn antenna sees the vertical polarized signals. Most home terminal operators equip their feed horn antenna with a simple TV antenna rotator which turns **not** the full dish (or spherical) antenna but rather rotates only the small feed horn antenna.

The satellites of primary interest are called COMSTAR D2 and D3, WESTAR I, II and III, SATCOM FI, FII and later in 1981 FIII; and, ANIK 'B' and ANIK II. Their locations and their frequency range assignments are shown in **Table One** here. Note that for most users of this Manual this group of satellites are largely southwest of you. The south is obvious; most users of the Manual are in North America or close by. The west is a matter of international accord. The nations of the world have agreed that certain locations **above the equator** will be assigned to certain nations. Largely the international satellite assignments attempt to place the respective national satellites more or less south of the country to be served. However where there are conflicts (such as Canada and the US) the more northern country usually ends up with the more due-south locations. One of the interesting side effects of national satellite assignments (national satellites are called 'domestic satellites' in the trade) is that because each is designed to serve primarily its own countryside it is possible for two satellites to occupy virtually the same location in space. The country of Columbia, for example, now entering the space satellite era, could place a satellite above the equator at almost the exact location as say the RCA FII satellite. They would operate **without causing interference** to one another because the antennas on the Columbia satellite would point at Columbia while the FII satellite would point at North America.

There are two categories of satellites in geo-stationary orbit. Category one are international satellites. There are two **groups** operating international satellites these days. The one you hear the most about is INTELSAT; an international political-business consortium of more than 100 nations of the world who have banded together economically to build and operate approximately a dozen satellites spread around the globe above the equator. Each nation that belongs to INTELSAT is able to rent or lease 'transponder time' on the INTELSAT system. They may use this 'time' to relay messages through the satellite to receiving terminals in their **own** country (such as Brasil does) or they may use the INTELSAT system to link to another country (telephone, data, television or all three). The US uses INTELSAT for a variety of purposes; the Washington/Moscow "hot-line" for example travels via INTELSAT. So too do daily US TV network news feeds. When you tune in the **ABC World News Tonight** through your local ABC outlet and see Peter Jennings sitting in London you are watching a satellite link fed from London to New York through an INTELSAT satellite hovering above the equator between South America and Africa.

By the nature of their coverage requirements, INTELSAT satellites broadcast relatively weak signals. And while it is possible, using typical 8 to 15 foot antennas, to **detect** the 'presence' of such international INTELSAT transmissions with the receiver to be described here, the quality of such transmissions would hardly be 'network'. Some INTELSAT transmissions are beamed to specific **areas** of the globe (rather than attempting to cover **all** of the visible globe at once). In this instance a typical home terminal (8 to 15 feet antenna size) will create a pretty decent picture. Brasil beams around 18 hours per day to a network of TV stations spread throughout the country via INTELSAT and these transmissions are beamed to all areas 'west' of the satellite. Since this satellite is east of Brasil, over the equator, it happens that the same signal level arrives in New York City as arrives in Sao Paulo (Brasil). Therefore in this case international reception, because of the nature of the transmission 'pattern', is available to you.

In still other (rare) circumstances INTELSAT satellite time or space is leased by a country on a special 'spot beam' basis. Australia is a good (and one of the few) examples of this. Australia is just now developing a complete national satellite policy. This country plans to have its own 'domestic' satellite system by the mid 1980's. On an 'interim' basis Australia is leasing transponder time and space on a Pacific Ocean region INTELSAT bird and they have 'bought' this service with the understanding that all of the available transmission power for that satellite transponder will be 'focused' directly on Australia (centered or bore sighted on the town of Alice Springs in the north). All of this means that the international satellites, operated by INTELSAT, have three operational options open to them. They can transmit signals to **all** of the globe they can 'see' from their above-the-equator location (that works out to about 40% of the globe surface), they can select **a portion** of 'their globe' and beam power to that region (Brasil's use of a transponder that beams signal only to areas west of the satellite location), or, they can 'zero in' on a small area using something called a '**spot beam**'. The net effect of all of this is that those transmissions transmitted to the 'whole globe' are spread quite thin and are weak; those directed at a part of the visible globe are stronger while those spotted at a specific region are strongest of all. To achieve a '**perfect**' noise free picture from such an INTELSAT satellite using a 'global' beam requires antennas in the 50-60 foot class. To achieve the same quality picture with an INTELSAT 'hemispheric' beam requires antennas in the 24-28 foot class. And to achieve the



Note: G - Global, E - eastern hemispheric, W - western hemispheric

Downlink Frequency (GHz)

DIAGRAM SIX - COMPARISON OF TRANSPONDER FREQUENCIES OF THE MAJOR 4 GHz SYSTEMS

same results with an INTELSAT satellite operating in the spot beam mode requires antennas in the 15-18 foot class. Keep this in mind because we'll come back to the matter of beam shaping shortly.

There is another class of international satellite, of interest to us. This category is operated by the Russian equivalent of INTELSAT; called Ghorizont (Russian for 'horizon'). The Ghorizont series of international satellites is not nearly as 'mature' as the INTELSAT family of birds. But is is growing and if the data released can be accepted at face value, it would appear that within another year or two the Ghorizont family of international satellites may be very 'competitive' to the INTELSAT birds.

Ghorizont satellites interest us primarily because they are constructed on a different premise than INTELSAT. It is believed that Ghorizont satellites can 'switch' between global, hermispheric and spot beam mode, the signal strengths received from these satellites are far stronger than INTELSAT satellites. **Ghorizont 2**, located at 14.5 degrees west (over the Atlantic) for example is received with perfect quality pictures all along the eastern seaboard of the USA with antennas no larger than 15 foot in size. The same transmissions are received simultaneously in Europe with excellent strength, indicating that the bird is in a 'global beam' configuration during such observations. At the same time **other channels** on the Ghorizont bird have been received in England at 'perfect picture' levels with antennas as small as 8 feet in diameter. This suggests that it can be seen that with the measured signal levels that the Ghorizont series satellites may be operating with as much as ten times as much transmitter power as our INTELSAT satellites. So while at the present time only the Ghorizont 2 satellite is visible in the US, and this only in the eastern 1/4th of the country (for those further west it is 'below the horizon'), additional Ghorizont birds planned are scheduled to be operated much closer to the US, on both sides. And since Ghorizont 2 already carries substantial European television (from both Communist and non-Communist countries) one must assume that as additional 'high power' Ghorizonts become operational that the opportunities for Americans or Canadians (or Columbians) to tune in direct, live, European television will multiply.The satellite phenominon is truly an international 'happening' and the new student of this fast growing technology should never lose sight of this fact.

So much for international satellites. There is another family of interest. In fact chances are your primary interest will not be with the international satellites but rather it will be with the second family called 'domestic satellites'. A domestic satellite is a geo-stationary satellite operating with some special type of 'spot beam' transmission system. The 'spot beam' on such a satellite is customized to cover the domestic territory of the country the satellite operates to cover. ANIK satellites (four now in flight, two of which carry television programs on some regular basis) for example beam their signals to Canada. WESTAR, SATCOM and COMSTAR satellites have a slightly tougher assignment. They are intended to cover the USA but that has to include some far apart territory including Puerto Rico to the southeast, Maine to the northeast, Alaska to the northwest and Hawaii to the southwest. In the process of covering Maine and Alaska much of Canada is also "illuminated" or covered by transmissions. In the process of covering Puerto Rico much of the northern and central Caribbean is also covered. Significant portions of Mexico are covered because of the southwestern USA proximity.

This would be a good point to tell you how to locate or find the satellites in your sky. You have to know where to point your antenna and then you have to do that exercise with considerable precision. There are two adjustments; up and down (called elevation) and side to side (called azimuth). The closer you are to the equator (i.e. the further south) the more 'up' the satellite will be.The closer you are to the southern California area (for North American viewers of domestic satellites) the more 'east' your antenna will point. This says that if you are in New England your satellite antenna for the most westerly of the US domestic satellites (presently RCA SATCOM FI) will be barely up and quite far to the west. A very detailed discussion of antenna mounts, pointing 'pointers' and satellite 'navigation' appears in STT's "**Gibson Satellite Navigator**" Manual. For a computer derived chart that tells you where to point your own antenna (up and down and left and right) to pinpoint any satellite in your sky, we suggest you send $4 plus your exact geographic coordinates (longitude and latitude to nearest minute) to **Bill Johnston, 1808 Pomona Drive, Las Cruces, NM 88001**. Ask for the geostationary satellite pointing chart.

Television is transmitted via satellite using a modulation technique called FM; or frequency modulation. This is a much different technique than is used for 'earth bound' TV and for this reason you cannot simply 'convert' the satellite frequency band down to standard TV channel frequencies and tune them in. The audio that goes with the TV transmissions is also sent via 'FM' using a **subcarrier** technique. Most of the domestic satellites of interest transmit their audio on either 6.2 or 6.8 MHz although virtually any subcarrier frequency between 5.4 and 7.5 MHz has and can be used on occasion.

To achieve good quality color (i.e. high fidelity video) the receiver must be capable of accepting and processing no less than a 30 MHz wide FM signal. The Howard Terminal receiver to be described does this by first down converting the 3.7 to 4.2 GHz satellite spectrum to a 850 MHz region "high IF" (intermediate frequency) and then after processing the signal in the high IF re-converting the signal down to a 70 MHz low IF. The signal is detected or demodulated (turned from radio frequency signals to so-called baseband signals which can be viewed on a TV monitor or listened to on an audio system) at the 70 MHz low IF. To insure that you receive all of the high quality television information present in the FM satellite signal, the 70 MHz low IF must be sufficiently wide or 'broad' to pass or accept all of the energy present. The magic number to do this is some place between 27 and 30 MHz. This means, as we shall see, that the 70 MHz low IF is really centered on 70 MHz but actually extends below 70 MHz and above 70 MHz by about 15 MHz. This results in a low IF that is typically 30 MHz wide. All of the important video and subcarrier audio energy is within that 30 MHz low IF bandwidth and we 'recover' or detect it there.

Most of the US and Canadian domestic signals are customized for satellite transmission by something called 'dithering'. Because the 3.7 to 4.2 GHz frequency band is **shared** with other (terrestrial) services the FCC decided years ago that domestic satellite signals must 'protect' existing terrestrial point to point microwave. One technique to do this is to build into the satellite downlink transmissions a special format which is designed not to interfere with the terrestrial service. All domestic satellite downlink transmissions are supposed to frequency dither (or FM **on top of** FM) their signal at a 30 hertz rate. The practical effect of dithering is that a 30 hertz (cycle) "blink rate" is added to the picture. If you view a satellite signal on a receiver that does not have a special circuit to eliminate this 30 hertz modulation the picture appears to have flicker across the screen. Fortunately technology has provided a low-cost way of eliminating this 30 hertz blink and in the receiver to be described the dither is eliminated by taking the baseband video signal after detection (demodulating) and running the video into an electronic 'clamp' that catches the top of the video signal sync tips (where the 30 hertz dithering waveform is carried) and clamping that portion of the sync tips to ground. This effectively and simply eliminates the presence of the dithering waveform.

THE RECEIVING SYSTEM

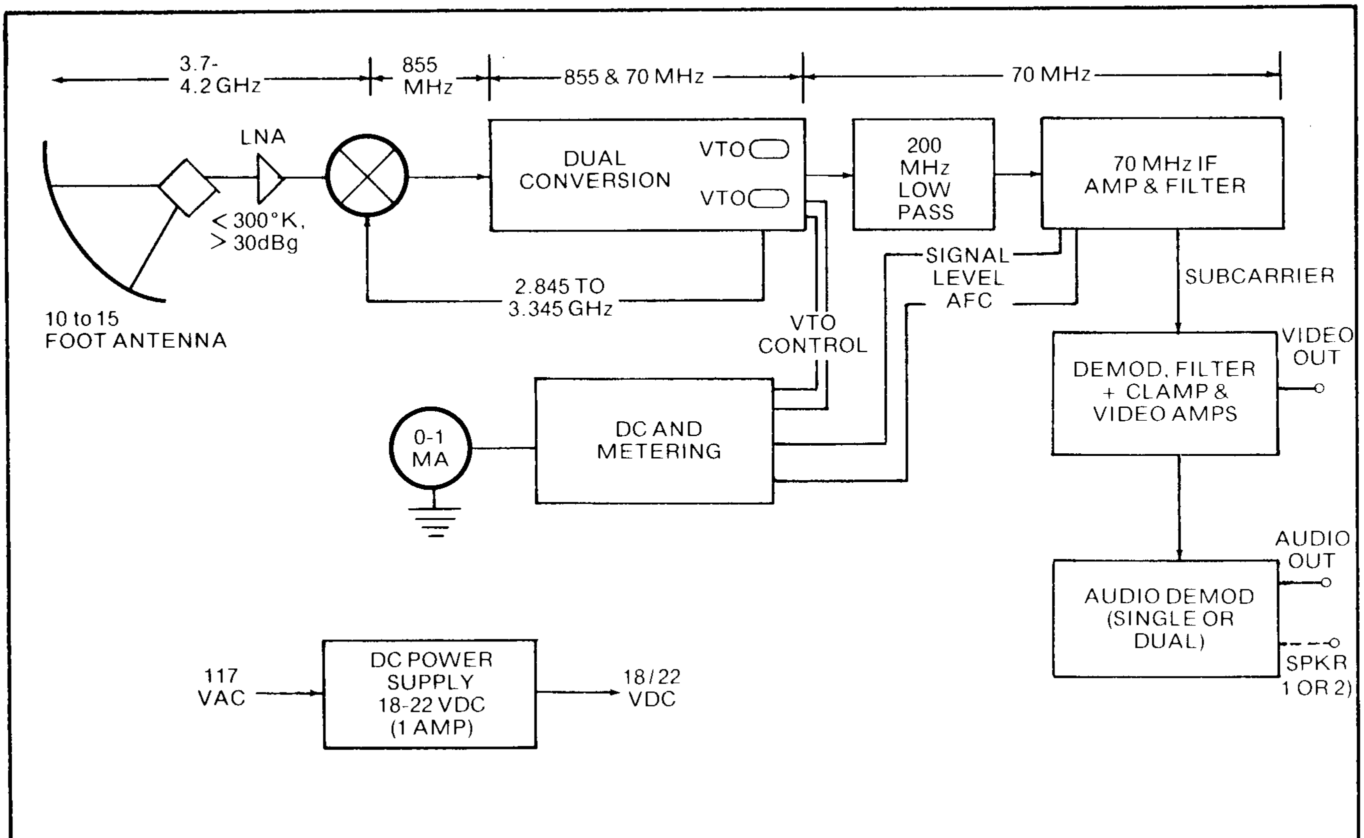
A block diagram of the Howard Terminal receiving system is shown here. The following paragraphs will describe the system, each block, and the circuit diagrams to follow.

Parabolic Reflector/Spherical Antenna - The first element of the system is the receiving antenna. Since it is our desire to catch as much satellite signal as possible (the more signal we intercept with the antenna the less expensive the receiving system electronics must be) the antenna is an extremely important part of the system. In this field at the present time there are two types of antenna configurations. The original and still most popular antenna form is called a parabolic; an antenna that duplicates the parabolic curve found in mathematical manuals and reference books. The parabolic antenna is actually a giant radio frequency 'mirror'; it catches signal from the satellite over its full surface area and then focuses this energy to a central focal point. **At the focal point** we install a smaller antenna called the pick up or focal point or feed horn antenna.

The parabolic antenna functions best when it is precisely constructed. Every point on its surface is capable of capturing signal and re-focusing the signal captured to the feed point antenna. However, the tolerances of the parabolic reflector surface are such that if the surface deviates from the ideal parabola form by more than plus/minus 1/16th of an inch the effective gain of the antenna is reduced. A thorough discussion of the design and construction of a low-cost (approximately $300) 10 or 12 foot parabolic antenna is found in the STT "**Nelson Parabolic Antenna Manual**". Note that the antenna system in use by the author is a 15 foot diameter antenna and that this **particular** antenna is covered (i.e. surfaced) with not a solid metal material but rather is covered with an expanded aluminum mesh. It turns out that it is not necessary to have a **solid** metal surface for acceptable antenna reflection efficiency; the author's expanded aluminum mesh surfaced antenna has opening sizes of 1/4" by 3/8" (uniformly over the surface) and the 'penalty' for not having a solid surface is on the order of a few percent of theoretical maximum gain. Mesh has mechanical advantages (such as when the wind blows; it presents a much lower wind load on the antenna structure) and can be considered totally reflective (transmission losses down 30 dB or more) when the holes are smaller than half a centimeter. If you have checked into the antennas offered in this field today you may have observed that there are solid metal surfaces (typically aluminum) and 'solid' fiberglass surfaces offered. The fiberglass is actually nothing more than a suspension medium, for within the fiberglass shell is either a fine 'spray' of metallic particles or more typically a fine wire mesh. **It is the metal** inside of the fiberglass which catches and focuses the satellite 4 GHz energy; not the fiberglass itself.

A more recent development, first popularized by the late Oliver Swan (STT produced a Swan manual in 1979 before Oliver died) is the spherical TVRO antenna. This is best thought of as a 'section' of a parabola; a sphere or 'slice' of a full parabola expanded to the desired size for the gain required. Numerous commercial spherical type antennas (such as the Torus licensed by COMSAT Labs) are available and there are versions available for the do-it-yourselfer as well. **Vidiark** for example offers a very popular line of 'backyard sphericals' from 8 to 12 feet in size. If you have seen one or have seen the advertisements you will have noted that the spherical surface is nothing more elaborate than a good grade of aluminum window screen!

So the reflecting surface material is not nearly as critical as many would have you believe. **What is critical** is the precise shape the surface takes and the accuracy it achieves when taking the desired shape. Whether you buy or build an antenna, the entire fate of the home system's performance rests squarely on the antenna's surface accuracy. There is nothing to stop you from being **more accurate** than +/-1/16th of an inch (reference the parabolic or spherical curve) but you should realize that there is a point reached where additional accuracy brings few results at the expense of greatly increased construction costs and time. If you could construct a 'perfect' curve parabola, for example, rather than one that had nominal surface variations on the order of 1/16th of an inch, you might achieve an additional 0.5 dB of antenna gain and perhaps a 10% improvement in antenna beamwidth. One half of one dB is not taken lightly in this field of endeavor but at some point the practical builder/installer must establish realizeable goals



HOWARD TERMINAL BLOCK DIAGRAM

for his customized antenna and accept slight degradation from the theoretically perfect antenna surface.

A table here shows what you can expect with antennas of various sizes. The beamwidth in degrees is the 1/2 power (3 dB) points of the antenna front lobe. Gain of the antenna assumes a reasonably efficient horn antenna at the focal point; 55% overall surface efficiency is cited. The LNA noise temperature required tells you what quality of LNA (in degrees of noise K or Kelvin) you must select if you wish a picture that is equal to or above receiver threshold with the Howard Terminal receiver described here; based upon your being in a +34 dBw EIRP or footprint area.

TABLE TWO

Parabolic Dish Antenna Parameters and System Noise Temperature (degrees K) required at 4000 MHz: (*)

Antenna Diameter [Feet]	**Beamwidth [degrees]**	**Gain [dB] 55% efficient**	**Noise Temp. Required**
15'	1.15°	43	300°K
12'	1.40°	41	190°K
10'	1.70°	39.5	134°K
8'	2.10°	37.5	85°K
6'	2.80°	35	48°K

* - footprint EIRP of 34 dBw is assumed.

It should be noted that antennas smaller than 8 feet in diameter have double strikes against them. Not only are they so small as to not produce useful gains for this service and application but their first sidelobe is in such a position that it may intercept the next satellite in the orbit belt. A further problem with even smaller dishes is that the first sidelobe frequently 'sees' the earth which is a hot (290K) noise source and the performance of the system is degraded by the earth noise. In spite of these problems there are a number of experiementers who are right now watching pictures with a Howard receiver on small antennas. Not studio quality video perhaps - but pictures none the less!

Most newcomers to the field ask about the multiple satellites now operational and what problems are encountered in 'steering' or moving the antenna from satellite to satellite. As recently as 1979 there was only limited television and therefore interest in any satellite **other than** SATCOM FI; the so-called cable TV satellite. However as FI filled up (20 TV channels now) with cable TV the program distribution game found transponders on other satellites. There is presently regularly scheduled (cable TV) programming on FI, D2 and WESTAR III. There is also regularly scheduled (meaning daily) programming on WESTAR I (PBS, VEU), III (SPN, SIN, XEW, Satori), COMSTAR D2 (seven different services) and ANIK B (three Canadian network channels). Forecasts for the next few years suggest the number of **full time** television transponders in use may reach 50 or more and on top of this there are another 20 or more with occasional television on them. Clearly the day of staying 'parked' on FI is past.

The particular antenna system in use by the author 'steers' from horizon to horizon. It happens to be a piece of surplus hardware found many years ago before the satellite TV craze came along; such finds are extremely rare today, at any price. There are now a couple of mechanized arm-chair controlled steering systems available (**Hero Communications Division** of AB Electronics, **Home Satellite Television Systems**) plus the STT "**Gibson Satellite Navigator**" Manual describes several do-it-yourself systems including one controlled by a search and find home computer interface and program.

The spherical antennas have one distinct advantage not found with parabolics. They have the ability to see (without moving the reflector surface; only the feed changes position) satellites spread over a 30 degree or so arc from your location. This means that for a typical mid-USA location birds from FI east to approximately ANIK B can be seen, or alternately birds from WESTAR III west to perhaps SATCOM FII. Unfortunately North American domestic birds are so spread out that a spherical cannot take in the **full** orbit belt so in reality the 'advantage' may turn out to be a dis-advantage to the person who 'wants it all' since the spherical **reflector surface** moves only with great effort or mechanical difficulty.

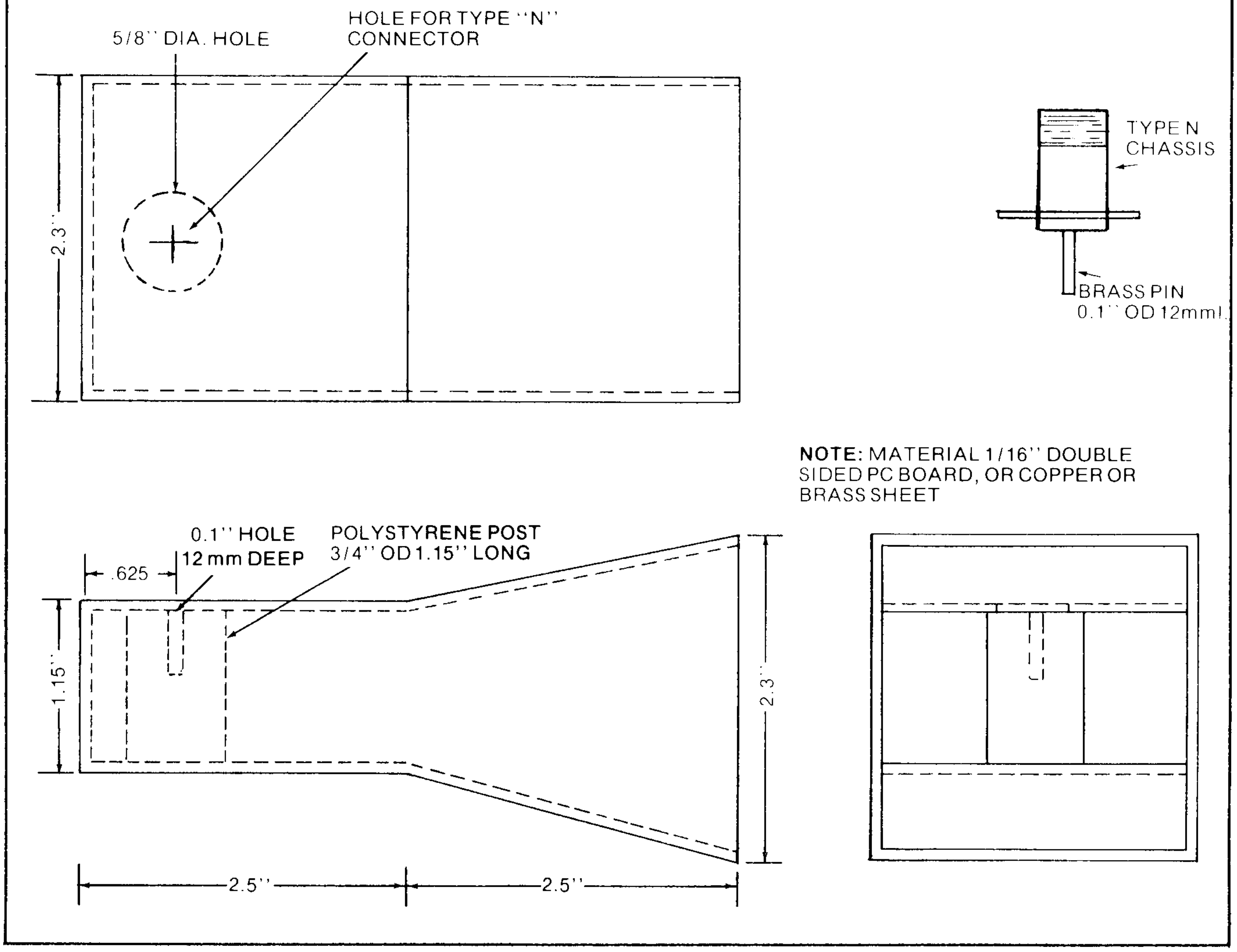
Another common question from people who come into this field from HF, VHF or UHF communications is 'Why don't you use large arrays of directive elements' (i.e. yagi) or colinear arrays)? The answer is that when multiple driven elements are coupled together for added gain the inter-connecting sections of transmission line become a problem at 4 GHz. Any practical line has more loss within the line than you are apt to make up with 'stacking'. The only antenna found useful at this frequency range other than the parabolic and its cousin the spherical is the 'Horn Antenna'. Unfortunately it requires far more physical size in a horn to achieve the gain one gets with a parabola so the horn is seldom utilized except in special applications where interference or noise is a severe problem.

In both the parabolic and spherical antennas the focused energy intercepted by the reflector is concentrated to a single point in front of the reflector surface. It is collected here by the focal/feed point antenna. One of the simplest yet most effective approaches to feeding your parabolic surface is with a simple horn antenna (see **Reference Data for Radio Engineers**, any edition under 'horn antennas'). A simple such design is shown here. For reference the 'standard' waveguide dimensions for the frequency range of interest (3.7 to 4.2 GHz) are 2.29 inches by 1.15 inches **inside**. A short waveguide section with a pick up probe and a horn can be easily built from brass or copper sheet soldered inside and out, or if you are very careful with construction from double side (G-10) circuit board.

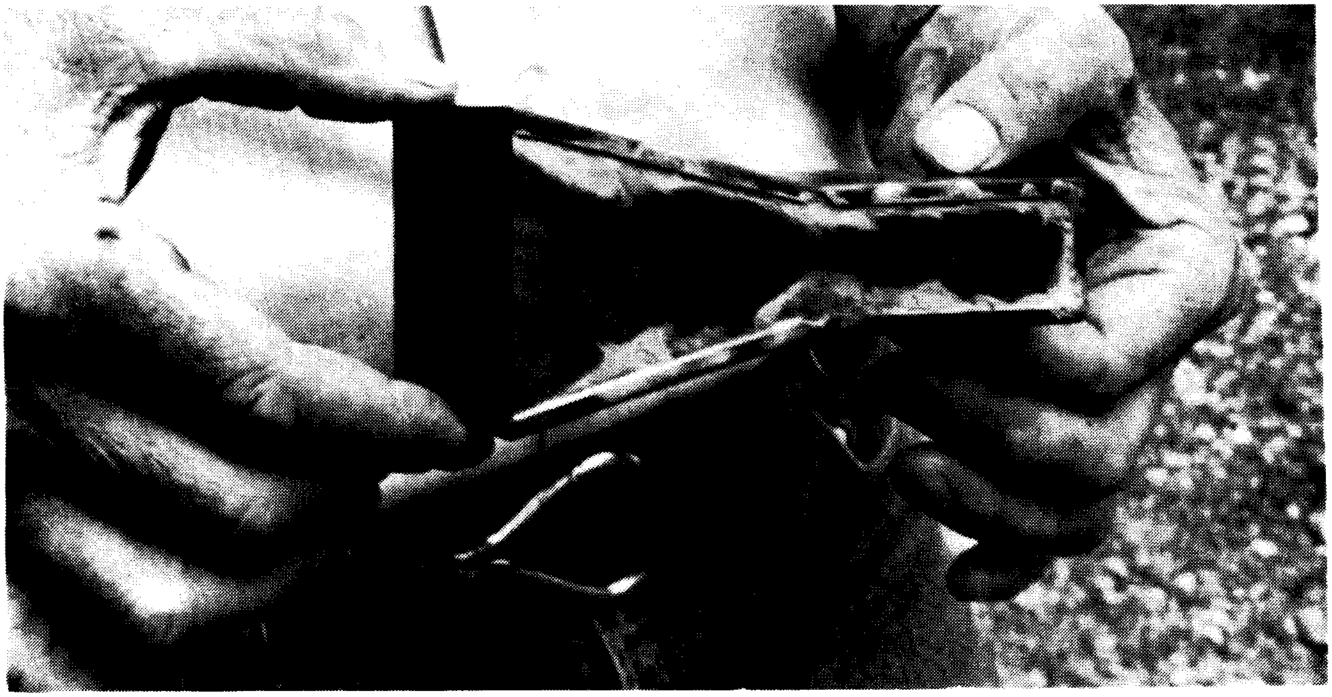
Dimensions for the feedhorn allow you to use it with any parabolic reflector with f/D (focal length to diameter) ratios in the .3 to .5 region. This horn could be mounted on three or four support legs along with a small platform for homebuilt LNA stages or if you utilize a commercial LNA the support legs (three are desirable, four acceptable) can form a pancake sandwich to hold the LNA plus horn in the proper position. If polarization diversity (horizontal plus vertical) is required a small TV antenna rotor or other suitable motor can be adapted to your particular mounting system.

The horn antenna has particular dimensions. These dimensions are performance conscious in that the length, width and amount of 'flare' determines the way the horn 'sees' the surface of the dish. It is desirable for the horn to have a view of the reflector surface such that the edges of the dish antenna

HOWARD TERMINAL FEED HORN



NOTE: MATERIAL 1/16" DOUBLE SIDED PC BOARD, OR COPPER OR BRASS SHEET



are 'down' 10 dB from the 'view' of the center of the reflector area. By tapering the resonse-sensitivity of the feed towards the edges of the parabolic surface we insure that 'earth noise' is not picked up by the horn and 'added to' the satellite signals present. Tests conducted on this horn design by Jack Trollman of Equatorial Communications shows the horn has edge-of-dish illumination of -11.4 for an f/D of 0.5, -14.4 dB for an f/D of .4 and -18.6 dB for an f/D of .3.

The term "f/D" may confuse you. It involves determining from the depth or curve of the antenna proper just where the focus point lies. The 'f' is the focal length, or the distance straight out from the front center of the dish to the point where all of the energy focuses. The 'D' is the diameter of the dish (the distance across the open mouth of the dish). In the trade a 'focal plane' dish is one where because of the geometry of the dish the focus point falls directly in a line along the plane of the antenna lips. The f/D of such an antenna is .25; that is, the focus point is 1/4 the distance across the dish surface (measured straight across, not along the curved surface). A 10 foot dish with focal plane geometry has an f/D of .25; or 2.5' (1/4th the D). A feed located at the focus point then will have to see the dish surface at an angle virtually 180 degrees wide; from dish edge to dish edge in all directions. This type of 'field of view' is very difficult to design a feed for and for this reason dishes with higher f/D's (indicating the focus point is further forward of the dish) are favored.

As the f/D increases the dish 'flattens out'; that is the curve built into the surface diminishes. Such dishes are called 'flat' (although they still have **some** curvature or they would not focus energy). If the goal of the dish system designer is an antenna with maximum gain, the ability to design a feed that will properly 'see' the dish surface becomes more practical with flatter dishes. However you can go too far with flattening of dishes since as dishes become flatter the feed to 'illuminate' the dish becomes **too good**; it starts to see around the edges of the dish to the ground below and behind and some place between .5 and .6 f/D there is a good chance that the feed antenna will have 'side lobes' or pickup away from the dish surface.

The commonly available Spherical antennas have an f/D in the range of 1.25 to 1.5. And since they are this **flat** they tend to have a high aperture efficiency (perhaps typically 70%) but poor noise performance. Parabolas improve this, but because of feed restrictions have a lower gain than might be expected.

All of this narrows down to a 'window' of f/D ratios; typically .3 to .5 f/D is the most generally accepted range. In this range there are compromises of good gain, achieveable feedhorn pattern design and rejection of unwanted 'side lobe' signals (interference). You can calculate the focal length of your particular surface (if it is not known) by measuring the diameter of the dish (a straight line directly across the center of the dish surface edge to edge; a 'plane' line) and then after locating the exact center of the antenna on this 'plane line' the depth from the center of the 'plane line' back to the surface center. Knowing these two numbers, apply this formula:

$$\text{focal length} = \frac{(\text{radius})\,2}{4 \times \text{depth}}$$

The LNA [Pre-Amplifier]

The **first** signal amplifier determines the **electronic** sensitivity of the total system. The first amplifier can be considered a single stage or a dual stage depending upon the design criteria. The LNA receives signal from the feedhorn. In the feedhorn design shown here a probe (metal) is inserted into the cavity at the back of the horn/short-section of waveguide and this probe collects the energy from the horn. The 'output' of the horn is a coaxial cable connector rated good to 4.2 GHz; typically a type 'N' connector. This connector is the 'output' of the horn and through a very short length of cable (a few inches at most) you carry energy into the first signal (pre) amplifier. The system shown here, with horn, pick-up probe and LNA stages, has been performing for the author for nearly four years. When it was first designed and constructed it provided 'state-of-the-art' performance; i.e. as good as anything else in the field for a reasonable price. However technology has a way of changing, constantly improving, and as the pages of **CSD** report monthly LNA prices (for commercial units) and performance has marched steadily on.

Perhaps if you are entering this field for the first time in 1981 or so you will want to consider the option of **purchasing** a commercial LNA and feed horn antenna. The noise temperature of the bi-polar LNA system to be described is in the 270-300 Kelvin range. By 1976 or even 1978 technology that was very good. More important than that however is the fact that the particular bi-polar transistors utilized in this LNA can be used by non-professional builders with good results. Until recently it was nearly impossible for the home builder to produce GaAs-FET amplifiers reliably. Now NEC devices can be used in purchased boards to achieve optimized noise temperatures of 120 Kelvin. Application note AN80903 from California Eastern Labs is very complete in this area. It is likely that a combination of the two types of amplifiers (GaAs-FET plus bi-polar) will prove best for the home builders. A near ideal package might consist of a pair of NEC GaAs-FET devices followed by two or three bi-polar stages. With a high performance feed such as the Chaparral 'Super Feed' (see closing remarks) you can bring a home constructed terminal into the high performance world of commercial terminals with ease.

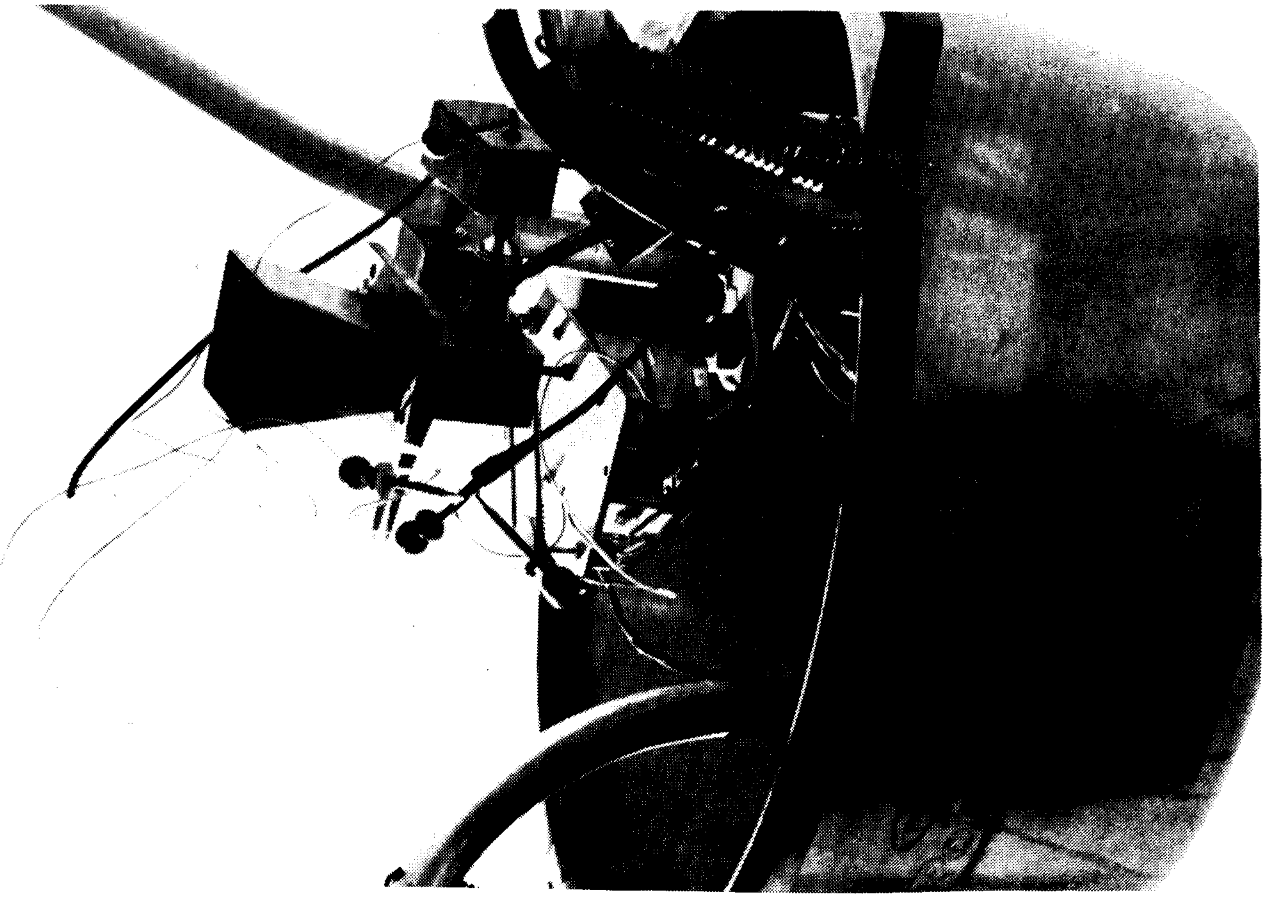
In either event the LNA must be as close to the signal pickup device as possible. As noted, the system described here has a probe inserted in the rear cavity of the feedhorn and this probe couples energy out of the horn and into the first amplifier stage. Commercial LNAs do this one step better; the probe is built into the LNA proper and the horn (less the cavity at the rear in the design shown) bolts directly to the LNA. The LNA supplies the probe plus the short section of waveguide that 'terminates' the horn design shown here.

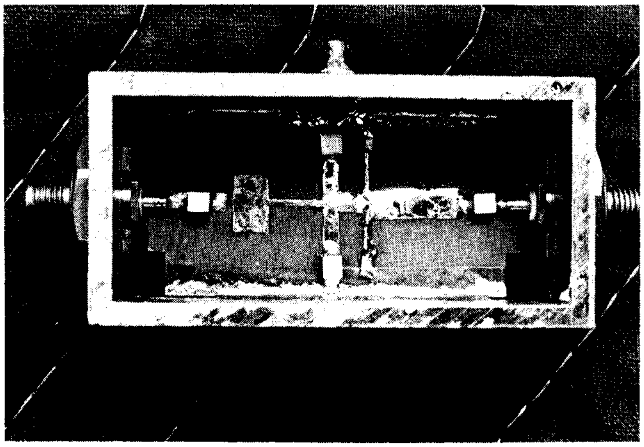
Any signal lost, between the horn and the first amplifier stage, is lost forever. It is not possible to re-create signal with an amplifier stage or stages. All an amplifier can be expected to do is to amplify the signal present. This function is called 'signal gain'. In the application cited here signal gain is important but not the most important consideration for the LNA. Something called noise figure or noise temperature is even more important.

All electronic circuits produce noise. Very good circuits, using very good amplifying devices, produce less noise than those not so good. In our application here 'noise' is the number one enemy of good system performance. We go to great care to design a feed horn plus reflector system that will pick up the maximum amount of signal from the satellite and the minimum amount of noise from the earth surrounding the antenna. The LNA stages are designed to amplify while at the same time producing as little noise of their own as possible. Noise produced in the first stage(s) of the LNA adds to the signal amplified and we have a 'ratio' established; the good stuff (signal) versus the bad stuff (noise). **Subsequent stages of amplification cannot change that ratio for the better**; they can only maintain it or if poorly designed make it worse. Thus the first amplifer stage(s) must have the lowest possible noise 'factor'.

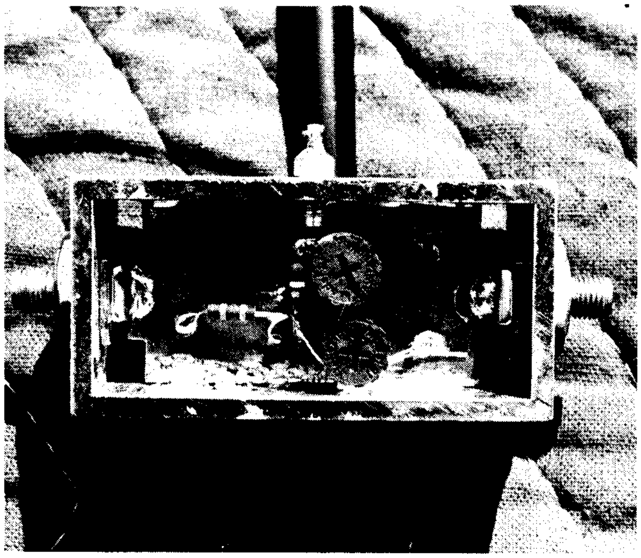
When we state that the LNA has a noise temperature of so many degrees Kelvin we are simply quantifying the noise factor of the first stages of the LNA. (Actually, saying degrees Kelvin is redundant since the definition of Kelvin is degrees Celsius above absolute zero. We shall therefore use the correct term which is simply Kelvins.) It is possible to calculate, in advance, if all contributing factors are known or from performance after the fact if the system performance is measured, the **ratio** of the desired (satellite) signals to the system noise. This measurement or calculation is called the C/N or carrier to noise (ratio). It works out that if your system will have a C to N in the 9/10/11/12 dB region you can expect good to very good quality pictures with your satellite TV system. On the other hand if your C to N is in the 7-8 dB region your pictures will suffer from being grainy or as they say in the trade, '**sparklies**'. There is a very narrow region in C to N between which there is some sparklies and no sparklies. If you can **increase** the C (short for carrier) by 1 or 2 or 3 dB or if you can **reduce** your noise (N) by a similar amount you can quickly and dramatically see changes in picture quality.

Therefore when you consider a 10 foot antenna and your studies indicate that a 13 foot antenna would produce an additional 1.5 dB of gain or so you can appreciate that this additional 1.5 dB is an improvement in the carrier; a significant





Single stage bi-polar amp as described.



Underside bi-polar stage. Mounting of multiple stages and feed horn to left.

improvement if your system is going to be in the below 9 dB C/N region to begin with. Or, if you can lower the noise factor by changing from a 300 Kelvin LNA to a 120 Kelvin LNA (which is equal in noise reduction to 4 dB) you can again appreciate this to be a considerable improvement in system performance. A note of caution is in order, for the important number is '**system** temperature' and not LNA temperature alone. Typical 0.4 f/D parabolas will have a temperature between 25 and 75 Kelvin depending upon look angle (lower look angles have higher noise temperatures because they place the antenna sidelobes closer to the 290 Kelvin earth). Sphericals will typically run 75 to 150 Kelvin. The noise temperature of your antenna must be **added** to the noise temperature of your LNA so the **real** improvement in system noise when you change from a 300 Kelvin LNA to a 120 Kelvin LNA is actually less with a Spherical than with a parabola; i.e. 3.1 dB in our example.

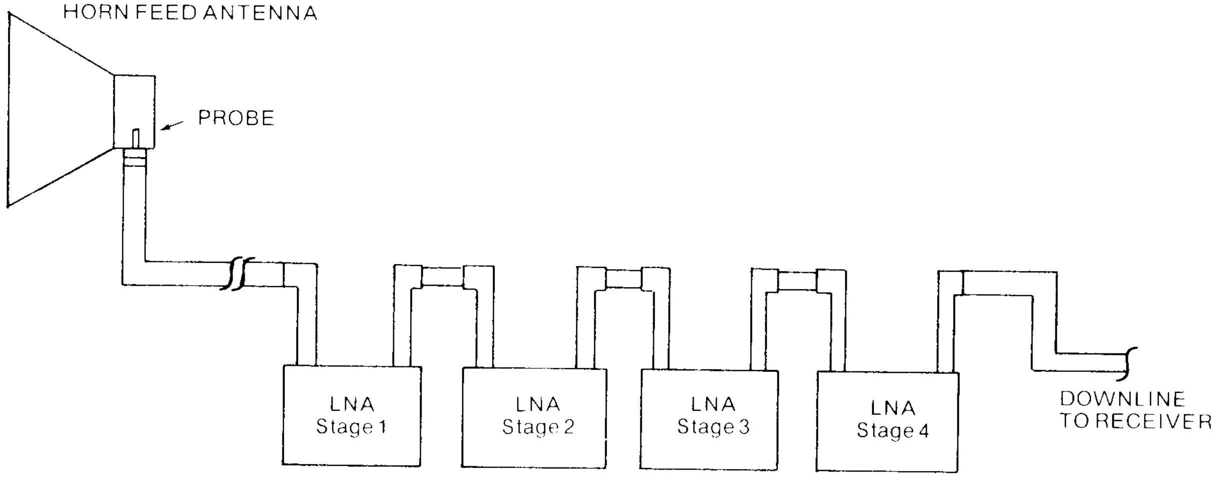
There are many-many ways for a system to 'lose' .1 or .5 or even 1.0 dB; quite by accident and with considerable frustration if you are attempting to locate the 'loss'. For example, coaxial cable connectors must be rated good at the frequency range of interest (4 GHz); especially when they will be inserted into the system **prior to** any signal amplification. (Connector losses become less important **after** the last LNA stage since the system noise temperature has largely been established by this point and pure voltage loss can be re-made up with subsequent stages.) All of this says do not consider **any** part of the system to be immune from sloppy planning. The satellite television system is an FM (frequency modulation) system and as such it is susceptible to something called '**FM threshold**'. Unlike the traditional 'AM' television system we have 'on earth' where a few dB of lost signal (C in our equation) cannot be 'seen' and probably not even measured accurately, a few dB of lost signal in the satellite circuit is of significant concern. This is why FCC rules, established for cable television and other 'licensed' TVRO terminals, require a 3 dB 'margin' (or excess signal) above and beyond the C/N that the system planner establishes as adequate for 'perfect' pictures. This is not a tough game nor is it difficult for the novice to grasp and put into practice. But is is an exacting science and you should never lose sight of that fact in all that follows.

The LNA described here is, as noted, **of bi-polar design**. Bi-polar transistors were the first available at **reasonable** pricing to achieve satisfactory noise temperatures in the 3.7 to 4.2 GHz region. As early as 1976-77 Hewlett Packard devices with noise temperatures in the 300 to 400 degree region became available and they provided an attractive alternative to then very expensive and difficult to work with GaAs-FET (Gallium Arsenide) transistors (field effect type). They are still attractive today because they offer 'amateur' or 'novice' builders an opportunity to put the circuits together with a minimum of test equipment and get satisfactory results.

The first stage utilizes the HP HXTR 6102 bi-polar and subsequent stages use the HXTR-6101. If you are going to use these as 'gain blocks' **after** a suitable GaAs-FET stage(s) you can use 6101s throughout. The first stage mounts as close as possible to the probe on the feedhorn probe/type N connector. If you equip your first stage LNA device (HXTR 6102) with a type N input connector you can avoid any coaxial cable between the output of the probe (type N) and the input to the first amplifier stage (also type N) by employing an Amphenol type UG 57B/U male to male type N fitting. This barrel-looking device connects the two N connectors together directly with a 'connector splice' rather than a coaxial cable jumper. Not only do you avoid any coaxial cable losses (slight **if** installed **perfectly** for short runs of a few inches) between the output probe on the feedhorn and the input to the first LNA stage, of greater importance you avoid the opportunity that the two male connectors on either end of the short jumper cable will not be properly installed resulting in unwanted signal loss. A male to male UG 57B/U can be expected to have around 0.1 dB of 'transition' loss at 4 GHz while a three inch piece of RG-214/U with a type N connector on both ends may have as much as 0.5 dB signal loss. Again, small losses **ahead of** the first LNA stage are **not small** when they are losses that cannot be subsequently 'recovered'.

Additional bi-polar stages can be mounted (as the author has done) in separate 'boxes' or they can all be constructed and placed into a single appropriately weatherproof outdoor container. The primary advantage to separate boxes is that you can 'mix and match' stages to realize the best sequence of stages for your particular system. While bi-polar devices are not nearly as subject to stability or operational deviations as GaAs-FETs, there **are variances** from device to device. You may find a particular series-sequence of the stages you build that functions best for you; something difficult to do if all three or four stages are 'ganged' in series inside of a single container. Stage to stage connections, if separate housings are employed, can be with low-loss cable and 4 GHz rated connectors or the UG57B/U male to male connectors suggested for the input to the first stage. In any event do not place more than a few inches of any cable (plus connectors) between stages.

The preamplifier stages are constructed generally following Hewlett Packard application note #967; available (and recommended) from your regional HP office. The

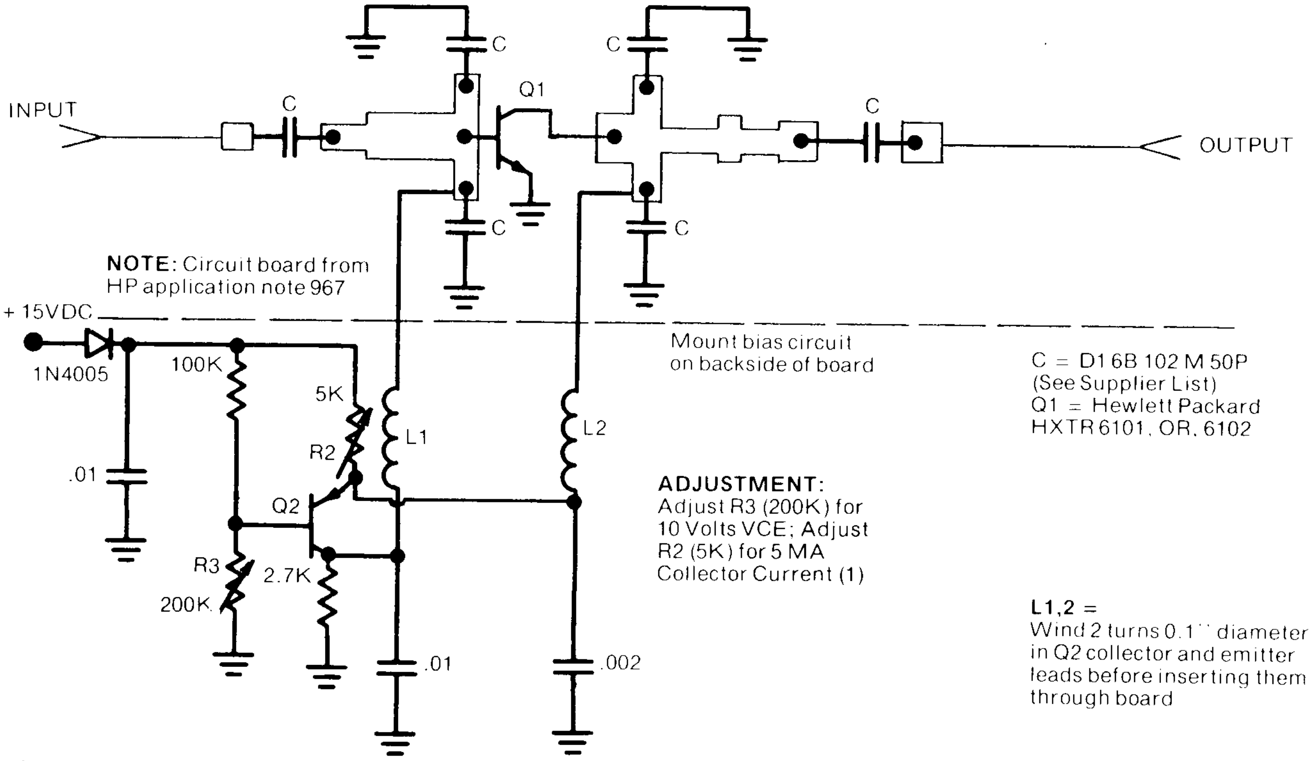


FOUR STAGES ARE CASCADED; EACH IN SEPARATE
MODPAK 7021 — 4 CASE OR EQUIVALENT SMALL BOX

amplifier stage (repeat three or four times depending upon gain required) circuit diagram, board layout (with PC board in actual size) and parts list are shown here. The stages must be constructed on Duroid type board (common G-10 board is very erratic at 4 GHz and is not recommended) and the capacitors specified must be utilized; low frequency type capacitors simply do not work at 4 GHz. Board material and capacitors, **or etched boards** ready for assembly have been available at reasonable cost from: **Robert M. Coleman, RFD 3, Box 58-A, Travelers Rest, S.C. 29690.**

It is worth discussing at this point just how much of the system should be located at the focal or feedpoint of the antenna. It has been the practice of commercial installations to keep as much of the electronics inside as possible since moisture, voltage transients (including lightning) and corrosion are not friendly to the sometimes tempermental 4 GHz circuits. Since any signal lost between the feedhorn and first amplifier stage is lost forever, it is apparent that some gain at 4 GHz must be located **at the feed**. The question is "how much" and in what form.

HOWARD TERMINAL BI-POLAR LNA STAGE



NOTE: Circuit board from HP application note 967

Mount bias circuit on backside of board

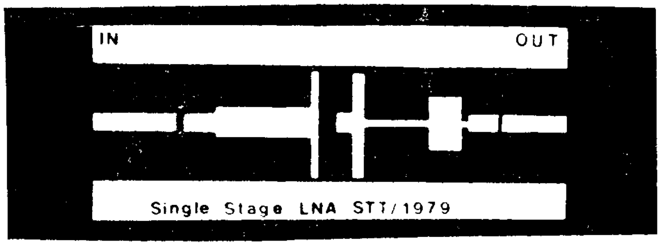
C = D1 6B 102 M 50P
(See Supplier List)
Q1 = Hewlett Packard
HXTR 6101, OR, 6102

ADJUSTMENT:
Adjust R3 (200K) for 10 Volts VCE; Adjust R2 (5K) for 5 MA Collector Current (1)

L1,2 =
Wind 2 turns 0.1" diameter in Q2 collector and emitter leads before inserting them through board

NOTE: All caps in bias cir. 5% ceramic disc
Q2 = 2N3906 or equivalent PNP

PC Board = MUST BE Duroid .031



Actual size single stage bi-polar LNA board.

One school of thought suggests that really **everything** should be at the feedhorn; and since the first version of this Manual was prepared back in late 1978 there have been substantive technology developments in this area. There are now on the market at least two complete systems that marry the antenna, the feed and the complete receiver into the feedhorn structure. One advantage to this should be obvious; even the best (and most expensive; $3.00 per foot!) 7/8ths inch coaxial cable has **some** losses at 4 GHz and while this loss occurs after the LNA and therefore after amplification has been applied to the weak antenna derived signals, it is still loss that must be made up later on in the system. By placing everything at the dish/feed, the signals that come inside from the antenna (on low cost cable) can be either baseband video/audio or they can be simple-to-handle American NTSC standard low band VHF TV signals from a remodulator fed by the antenna-mounted receiver system.

The primary disadvantage to this approach (and variations to it which place at the antenna the LNA plus perhaps the first downconversion stages as far as the first IF output) is that anything that can happen, bad, will happen faster outside in an uncontrolled environment than it will happen inside where some semblance of constant temperature and humidity is possible. Any receiver, regardless of design approach, must employ at least one microwave frequency range 'oscillator' to cause the 4 GHz input signal to 'downconvert' through a mixer to a more manageable lower frequency (IF). Even if price is not a consideration (and it usually is) such microwave frequency range (local) oscillators tend to be extremely temperature sensitive. That says that when the temperature they operate in oscillates or drops they change frequency; whether you want them to or not. There are of course AFC (automatic frequency control) and AVC (automatic voltage control) circuits around that can totally or partially compensate for such unwanted excursions but when you start adding additional parts or circuits to adjust for changing environment you are increasing both the size, complexity and cost of your basic system. It may not be a good trade off although certainly the day will come when it is the preferred way to do things at 4 GHz.

Primarily however it is assumed that you have purchased this Manual because you are seriously entertaining the thought of constructing some or all of your own TVRO receiving system. This suggests you are not frightened by electronic construction and most important of all you will want the ability to update the basic reciever system from time to time as better devices and circuits become proven and available. This argues strongly for two design criteria:

1) **Keep the system modular** so that individual segments can be worked on independently from each other (putting every part of the receiver on one large circuit board may not be the best choice), and,
2) **Keep as much of the system inside as possible** since that is where you will be wishing to make the circuit adaptations, updatings and doing side by side comparisons between the 'old way' and the 'new way'.

This final note on amplifier technology in early 1981.

LNA devices (full amplifiers) for the home builder were not a good price to performance trade off in 1979; when the first version of this Manual was prepared and distributed. In the interim LNA prices and performance have improved dramatically. Today you can purchase 120 degree (1.5 dB noise figure) low noise amplifiers for $795 in lots of one from numerous sources (see **CSD - Coop's Satellite Digest** from STT) and if you do some shopping you can chop another $100 or more off of that. 100 degree LNAs, considered extremely exotic in 1979 are now available in the under $1000 range from the same sources and the almost unheard of 85 degree LNAs barely available at any price in 1979 are now widely advertised for under $2,000. **These are** large dollar numbers but they offer you a choice none the less which for any reasonable price was **not available** in 1979.

The Receiver

When the first issue of this original Manual was distributed at SPTS '79 in Oklahoma in mid-1979, for most of those attending the Manual was their first 'hands on experience' with 4 GHz receiver technology. Several hundred experimenters read and duplicated the receiver described in that premiere Manual using point-to-point wiring techniques, lots of human intuition and probably forty to fifty hours of construction time each. Because point to point wiring offers the builder hundreds of "do it this way" or "do it that way" **choices** many system builders experienced some difficulties in making the system properly function. From the feedback of these early builders the author and fellow satellite terminal pioneer Robert Coleman set out to create a complete set of circuit boards which would, if used, greatly reduce the opportunity for error because of point-to-point wiring **choices**. The Howard Terminal Receiver described here is for those circuit boards which have now been generally available for slightly more than one year and as such have been around long enough for the author to know that all major bugs, design flaws and opportunities for mis-interpretation by the reasonably competent builder have been eliminated.

This has been learned by those who have built up these boards following data sheets provided with each board set:

1) **Layout** of the individual boards in a chassis seems to be very uncritical. Versions with boards 'stacked' atop one another seem to perform every bit as well as versions with boards neatly laid out one-deep and side by side.

There is this caveat, touched on briefly previously in this Manual. The logical 'next step' might be to place everything on **one** board so as to eliminate the various board to board connectors, isolation capacitors and individual voltage regulators. The reader should be warned that this can (and usually does) cause considerable problems which can only be rectified by going back and doing **original design engineering** all over again. Two versions following this approach have been created by the author for licensing to commercial manufacturers and the author assures you that Murphy's Law ("anything that can possibly go wrong...will") has not been repealed. It, like the law of gravity, is still with us. Home constructors are therefore urged to stick to the modularized board by board approach, using the boards developed for this purpose and now built up by more than 1,000 home builders. Please note that the first question the author will ask you if you come to him for consulting assistance (see page one) is "What modifications did you make from the Manual and circuit board sets?"!

Dual Conversion Board

The circuit diagram and the parts list are shown in diagrams A and B. The top and bottom of the dual conversion board are shown in diagrams C and D.

A **VARI L model DBM 500** mixer is used for the first conversion; getting you from the critical 3.7 to 4.2 GHz range down to a more manageable 800 MHz region UHF region. This is about the least expensive of the quality mixers currently available in the marketplace although it is not the only such device. If you are apt to look for a substitute you should be searching for a mixer that is usable between 3.7 and 4.2 GHz (input frequency range) which can produce an intermediate frequency signal between 800 and 900 MHz (high IF) with a (conversion) 'loss' of not more than 10 dB and with a local oscillator power requirement of between +7 and +9 dBm. In the version shown the mixer has been mounted to the dual conversion board by drilling three holes in the board for the pins. This works well although in numerous other versions the

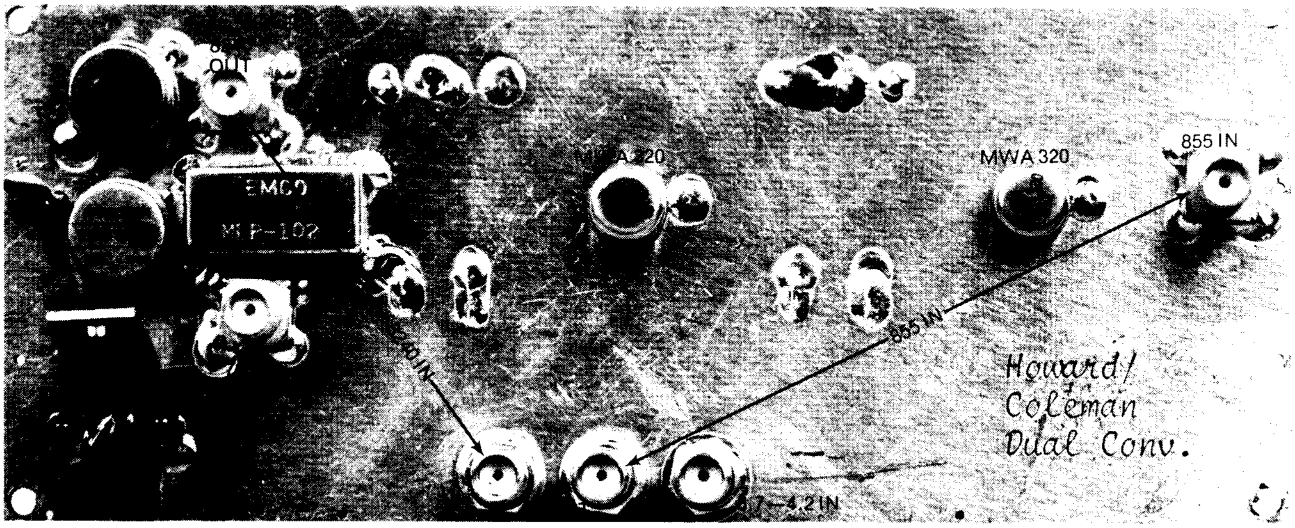


Figure C

author has mounted the mixer outside of the box with equally good results.

Construction of the board is straight forward. If you are getting into this field with the purchase of this Manual we must also assume that you will be acquiring circuit boards of current or present vintage. On the chance that you somehow have acquired an older set of these boards you will notice that grounding holes at the bottom of the filter lines are missing (see diagram here). These are indicated by a letter 'S' and should be drilled (four holes in all). A grounding wire (clipped end of resistor or capacitor OK) is inserted through each of the four holes and soldered on both sides of the board; end of filter elements on one side and the circuit board 'plane' on the opposite. Any place you see 'S' markings on circuit boards indicates through-board grounding as described here.

Prepare the boards for assembly by drilling the mounting and connector holes necessary for your particular receiver. Many home builders have found that rather than installing individual coaxial connectors on each board that you can get excellent performance by simply selecting a good grade of subminiature 50 ohm coaxial cable and carefully soldering the center conductor and a **short** section of the braid to the appropriate traces on the board. This saves money but it also makes testing of modules more complicated. Insert the required grounding wires through the board and solder both sides. These plane to plane or trace to plane wires are very important; they must be in place and they should be short and not wander about the board.

Next install the other components as shown in the figures.

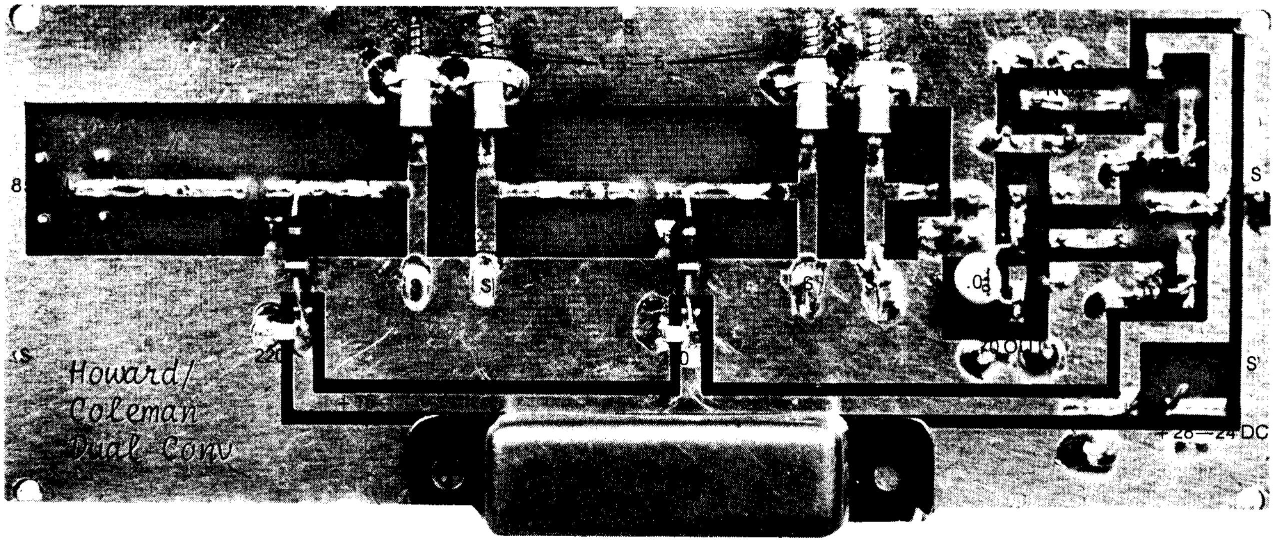
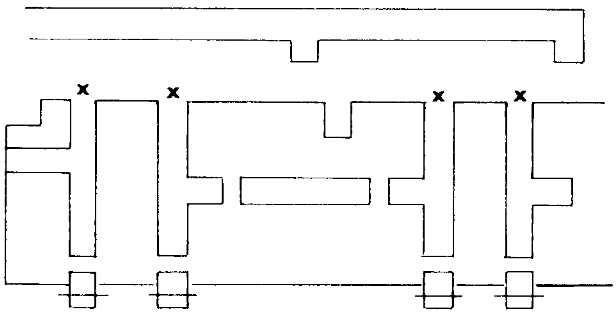


Figure D

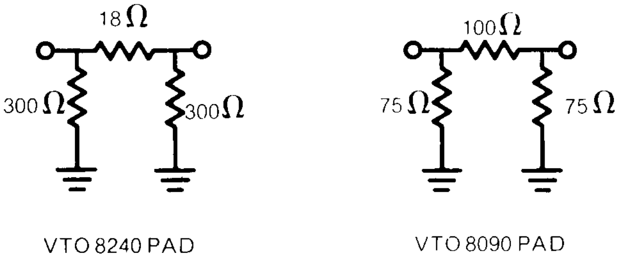
DUAL CONVERSION bandpass filter - should you have this board with**out** holes in the board at the end of the filter (see four X marks on layout below), drill holes and insert wires and solder on both sides of board.



The MWA 320s and the two VTOs must be placed firmly to the board and their mounting tabs soldered directly to the foil. The mounting kits which come with the VTOs are not needed and can be discarded. (Note: you should inquire if you can purchase the VTOs less the mounting kits, and if you can, how much money you can save in the process. This has been a 'flexible' decision of the supplier in the past.) Notice that in the photo figure for the bottom side of the board there are 'note' remarks adjacent to each VTO output line. Each of these (two) lines should be cut and an attenuator added from the diagram appearing here.

1) **Use 1/8th watt carbon resistors** with very **short** leads in making up these attenuators; or chip resistors.

It has been found from hundreds of system duplications that most receivers will operate properly with**out** these attenuators. **However**, not all VTOs are created equal and some (in particular the VTO 8240) may do undesirable 'frequency hopping' when encountering a mixer load (slight variations in the mixer load impedance may also be causing some of this to occur). Further, both of the VTOs are very conservatively rated and appear to **always** meet or exceed their output power ratings. Thus 'giving up' a small amount of output power to the pad, to 'force an impedance match' is not a performance degradation decision.



HOWARD [COLEMAN] DUAL CONVERSION BOARD PARTS

Capacitors

6	220 pF chip (VITRAMON)
2	4.7 MFD at 35 volts
2	.01 disc ceramic at 50 volts
4	1.5-5 pF piston trimmers (TRIKO)

Resistors

2	470 ohm, 1/4 watt
2	300 ohm, 1/8 watt
2	75 ohm, 1/8 watt
1	18 ohm, 1/8 watt
1	100 ohm, 1/8 watt

Integrated Circuits

2	MWA 320 (Motorola)
1	7815C voltage regulator in TO 220 case
1	VTO 8240 (Avantek
1	VTO 8090 (Avantek)

Diodes

2	Silicon 1N4005 or equivalent

Mixers

1	DBM 500 (VARIL Corp.)
1	MLP 102 (Engelmann Microwave)

Connectors

3	SMA chassis (E.F. Johnson; optional)

FIGURE B

The circuit includes protection diodes in the VTO tuning leads to insure that the user does not 'zap' an expensive VTO by applying a reverse voltage. Although there are no negative voltages required in this version of the Howard Terminal Receiver it is still possible to produce negative transients of sufficient amplitude to destroy VTOs if you accidentally short certain components while 'hot'. It is therefore best (even mandatory) that you **turn off the power** before working on either the power supply or anything in the DC control card circuits. Also note that you can and should check the VTO orientation (i.e. proper pin locations) prior to inserting the device onto the board by noting which pin is grounded to the case proper.

The Triko tuning capacitors have three leads. Two of these penetrate the board and must be soldered on **both** sides and the third is bent so as to be soldered (flat) against the PC trace indicated. Please note that the capacitors specified here have brass tuning slugs. The key word here is **brass**. Be careful to not accept any substitution(s) which employ steel tuning slugs; they will not work properly at the frequencies in this circuit.

The coupling and bypass capacitors (specified at 220 pF) are **chip** capacitors. Their value is not particularly critical although it is suggested that equal values be employed throughout where specified at 220 pF. Values from 220 pF to 1,000 pF have been substituted without problems.

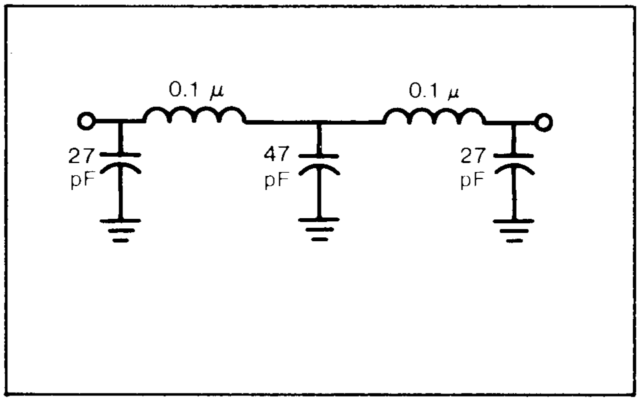
Orientation of the Engelmann MLP 102 mixer can be verified by noting which pins are attached to the case. In the past some builders have soldered the mixer to the top of the circuit board; the author no longer recommends this practice. A better approach is to drill a pair of holes through the board adjacent to the mixer near where the grounding pins of the mixer penetrate. Run grounding wires through the board at these locations tying the two 'planes' together; short leads and solder.

When DC is applied to this board the circuit should draw around 150 mA and each of the MWA 320 amplifiers should have about 3 volts DC on their respective RF output traces. The VTO supply terminals should show 15 volts DC (+/- 1 volt).

In this particular version of the receiver the high intermediate frequency (IF) chosen is centered at 855 MHz. This places the VTO 8090 local oscillator source in the 925 MHz range. Experience with this VTO tells us that when you have 2.4 volts on the voltage-tuning terminal of the VTO 8090 you should be very close to 925 MHz. The reason for selecting this operating frequency for the IF and LO is that four times 925 equals 3,700 MHz (3.7 GHz) and we thus minimize the potential for the fourth harmonic of this VTO to fall inside of the 3.7 to 4.2 GHz band and cause interference to the input RF signal. The harmonic is also a good 'band edge' marker and will produce a black screen when tuned in.

200 MHz Low Pass Filter

Some builders may find the need for the 200 MHz low pass filter wanting. The truth is that the receiver **will** function **without** this filter but there is sufficient 925 MHz energy coming out of the receiver second mixer that the purist is (or should be) uncomfortable and those who might wish to make accurate C/N measurements will find it virtually impossible without this filter. It is therefore highly recommended by the author that a simple low pass filter consisting of two 'chokes' and three capacitors be added between the dual conversion board (output) and the 70 MHz low IF (input). This filter could be built on a separate small piece of PC board or it can be added to the standard 70 MHz IF boards available by drilling a few holes in the blank area near the input. The circuit is shown here. Use very short leads in construction.



70 MHz Intermediate Frequency Board

The circuit diagram and parts list are shown in diagrams E and F. Top and bottom (board) views are seen in diagrams G and H respectively.

This circuit provides a nominal 43 dB of 70 MHz IF gain with an input and output impedance of 50 ohms. The five section bandpass filter is flat (to within +/-0.5 dB) and it can be aligned or tuned for IF bandwidths from 22 to 35 MHz.

Prepare the circuit board by drilling the mounting and connector holes necessary for your receiver. Also drill the five holes required for the bandpass filter coils. Insert the parts as shown in the illustrations making sure that the MWA 120 cans are firmly down on the circuit board and that the (mounting) tab on each is properly soldered to the foil.

The Miller coil forms are to be wound with #26 (or lighter/smaller) wire. It is advisable to wind the coils closest to the upper (open-hole) end of the form so that you get maximum tuning range. Insert the coils into the circuit board per the illustration. Point to point wire the capacitors beginning with the 22 pF values from the various coils to the closest (as shown) ground plane point. There are three of these capacitors and they should connect from the ring that fits around the form closest to ground directly to ground. The balance of the connections are obvious; inspect carefully to verify that the filter agrees with the illustrations.

The total current drain of the IF amplifier is around 90 mA and the voltage present on each MWA 120 should be approximately 5 volts.

The 70 MHz bandpass filter is the only segment of the receiver that requires any **special** tune up by the builder. This is a plus to this design since this alignment process is done at the relatively 'safe' frequency range either side of 70 MHz. This is a frequency range where test and alignment equipment is readily available; most TV service shops have a sweep alignment system which at least is functional in the standard TV set 45 MHz IF region and many have sweep systems with markers and detectors that will function to at least 100 MHz. Another source for test gear is your local CATV (cable television) company. CATV systems commonly have 0 to 300 MHz 'sweeper test sets' in the shop since cable TV line amplifiers function in a good part of this region.

HOWARD [COLEMAN] 70 MHZ IF PARTS

Capacitors

7	.01 disc ceramic at 50 volts
2	4.7 MFD 35 volt electrolytics
1	10 pF 5% dipped micas or 5% ceramics
5	22 pF 5% dipped micas or 5% ceramics
1	18 pF 5% dipped micas or 5% ceramics
1	33 pF 5% dipped micas or 5% ceramics

Resistors

2	330 ohm, 1/4 watt

Coil Forms

5	J.W. Miller 4500-4 or other ¼" dia. slug tuned forms will also work.

Integrated Circuits

3	MWA 120 (Motorola)
1	7815C voltage regulator in TO 220 case

Figure F

There is no good way to align this filter however without a sweep alignment system. A brief description of the circuit will tell you why.

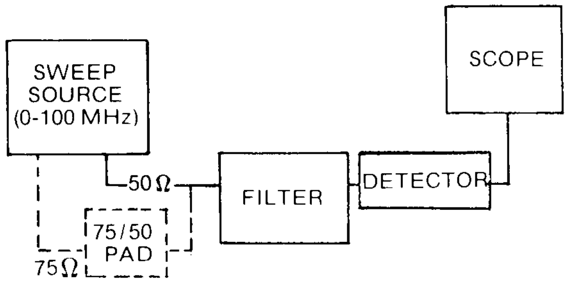
What you wish to have when finished is a uniformly flat bandpass that extends either side of 70 MHz by some specified amount. The 'flat' portion of the bandpass must be **no less than** 22 MHz wide (which extends from 59 MHz to 81 MHz) and **no more than** 34 MHz wide (extending from 53 MHz to 87 MHz). The decision of how wide to align your 70 MHz IF involves the following thought processes:

1) **Fact One:** A narrower IF provides **improved** carrier to noise **ratios**. This suggests that you want a **narrow** IF.
2) **Fact Two:** A wider IF produces **improved** picture **clarity** and detail. This suggests you want a **wider** IF.
3) **Fact Three:** You definitely cannot have **both** at the same time!

Now if you are going to be operating the receiver with a marginal antenna system (i.e. an antenna smaller than you would really feel comfortable with at your location) and/or with an LNA that is not as low in noise as you feel you really should or would have if you have a clear choice, you will probably be better off with an IF aligned closer to 22 MHz wide than to 34 MHz wide. This narrower IF will give you a fractional improvement in system C to N at the expense of high definition color. BUT - if you are going to be slightly below threshold or right at receiver system threshold with your system, sparklie noise (caused by being at or below threshold) will mask picture detail anyhow. So it is better to do something to reduce sparklies than to worry about superb color definition.

Any IF narrower than 22 MHz begins to do nasty things to the chroma (color) and many also greatly (or measureably) reduce your audio subcarrier level(s) making it more difficult to recover clean audio. In the high dollar commercial receiver area most receivers are aligned to one of two IF bandwidths; either 27 MHz (in which case the manufacturer makes certain claims for 'threshold extension' for his receiver, touting the receiver's ability to perform well in weak signal situations) or 34 MHz (in which case the manufacturer makes claims for high quality color definition).

Having decided how wide to make your IF (something you can go back and change on your own later on if you wish by merely re-aligning the filter) let's get you back on the alignment track. The three coil forms in a straight row are (HP) high pass, (MP) mid pass and (LP) low pass as labeled. This means that as you approach alignment maturity you will see the highest frequency portion of the selected IF passband move or wiggle when you tweek on the HP coil form. Similarly the mid pass will move the middle of the frequency range about (the one closest to 70 MHz) and the low pass will juggle the low end (near 60 MHz) about. Then we have two additional coils mounted side by side; one is marked low notch (LN) while the second is marked high notch (HN). As you move the LN adjustment about you should see the lower frequency edge of the display bounce around quite dramatically. You are 'shaping' the lower skirt of the passband with this coil slug, determining just where (and how sharply) you roll off the lower frequency edge of the passband. The HN does the same thing at the opposite end of the passband.



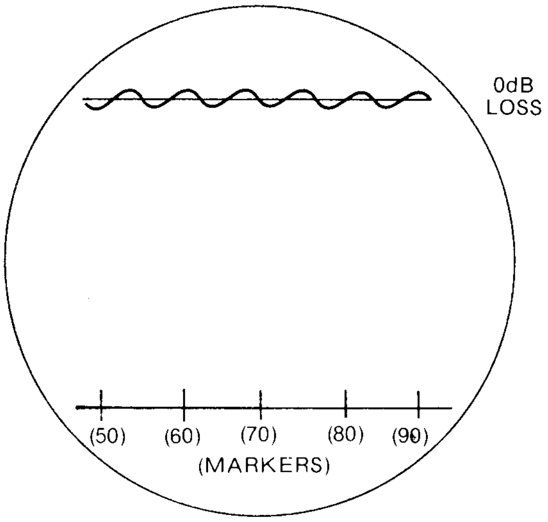
BASIC SWEEP SETUP

The very first adjustments to be made can be done simply with a signal generator and voltmeter (detector). Set the generator to 90 MHz and adjust the HN for minimum reading. Then set the generator to 50 MHz and adjust LN for minimum. Setting HP, MP and LP to 'mid-position' will then get you ready for sweeping (some builders report adequate if not perfect pictures at this point).

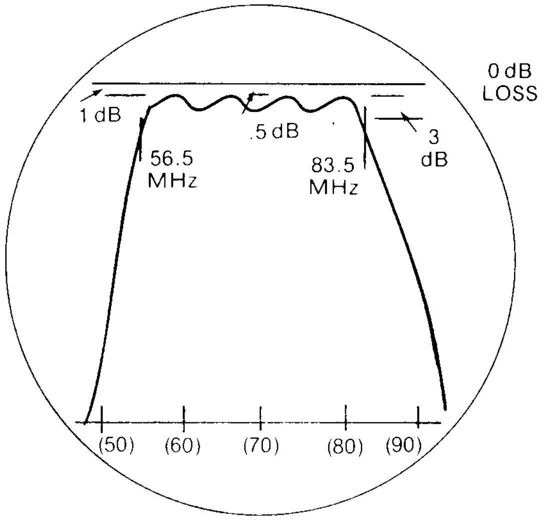
Familiarize yourself with the sweep system you will use. Determine how if you connect the sweep output (at some predetermined power level such as +20 dBmV or 10,000 microvolts) directly to the detector/scope display you can see the full sweep power on display. Play with the frequency markers (you should have no less than 10 MHz markers so you can pinpoint 50, 60, **70**, 80 and 90 MHz on the display) so you know where on the scope display the various frequencies fall. Take a grease pencil and mark the scope screen with the appropriate 10 MHz markers.

Having determined where on the vertical scale the full sweep output falls and where on the horizontal display the markers for each marked frequency falls, connect up the sweep output to the filter input and the filter output to the detector. You may not see anything at this point since the filter has not been aligned and it represents a giant untuned circuit to the sweep. See if you can increase the sweep output power and/or increase the vertical sensitivity of the scope/detector to see **any kind** of display at all. When you have found a display then you can begin tweeking on the coil forms. First adjust the high pass (HP), mid pass (MP) and low pass (LP) coils. Adjust so that your dispaly shows greater display height (vertical range). As you turn the coil form adjustments you will start to get sufficient signal through the filter that you can reduce the sweep output back to the original voltage setting (+ 20 dBmV in our example) and/or the scope vertical sensitivity back to the setting where you made your initial no-filter comparisons.

Your ultimate goal, only adjusting HP, MP and LP is to get the display 'flat' between say 60 and 90 MHz (give or take a little) with as little 'loss' as possible. The sweep system will be calibrated so that you can determine how far (in dB or parts of a dB) your rough aligned filter is from having **no loss**. If your sweep system is a 75 ohm system (as most are) you will have to make some allowances for the fact that your filter is 50 ohm so it does not present a perfect load to the output of the sweep and the input of the detector. Some sweep systems include external matching pads for alignment of 50 ohm equipment; others tell in their manuals how much allowance to make and where.



SWEEP DISPLAY "STRAIGHT THROUGH," BEFORE CONNECTING FILTER



NEAR-IDEAL SWEEP DISPLAY AFTER ALIGNMENT OF FILTER (27 MHz IF BANDWIDTH

In 75 ohm terms, the filter when completely aligned should exhibit between 1.5 and 1.0 dB of through loss. You can get pretty close to no loss with patience and by adjusting only HP, MP and LP but you are not done yet. We have the high and low notches to complete.

The tuning combinations of the HP, MP and LP will get you a sweep pattern that is not only nearly-no-loss but if done properly the variation (ripple in filter talk) will be +/- no more than say 0.5 (1/2 of a) dB. It is important to **not have** big peaks and valleys in the filter sweep since they mean that those

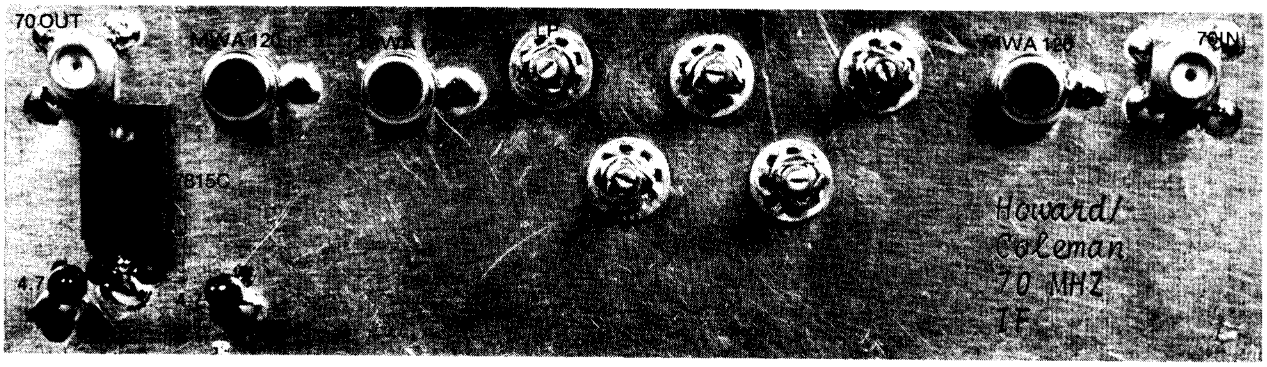
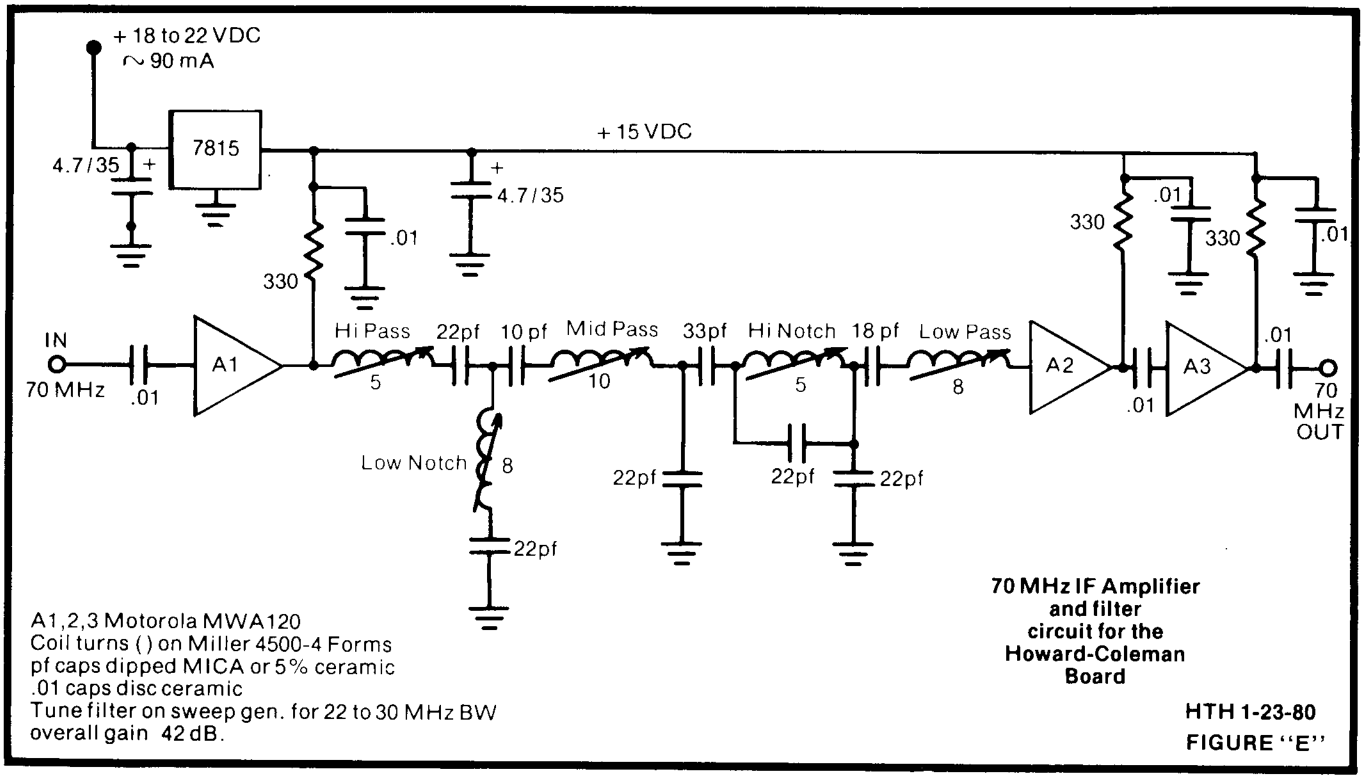


Figure G



A1,2,3 Motorola MWA120
Coil turns ( ) on Miller 4500-4 Forms
pf caps dipped MICA or 5% ceramic
.01 caps disc ceramic
Tune filter on sweep gen. for 22 to 30 MHz BW
overall gain 42 dB.

70 MHz IF Amplifier and filter circuit for the Howard-Coleman Board

HTH 1-23-80
FIGURE "E"

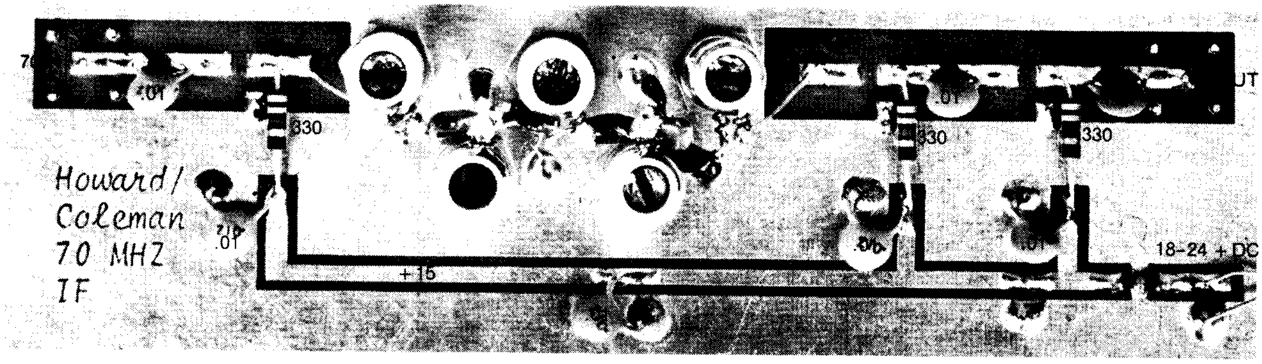


Figure H

portions of the IF falling down into a valley will get to the detector weaker than those at the top of the peaks. Too much variance here will cause your picture to lack snap and detail; it can even wash out colors and cause smear.

Now finish with either the LN or HN and see how your carefully constructed 'flat' response starts to wiggle around. As you tune HN towards the top end you have to keep in mind how wide you want your IF. If you elected 22 MHz then you want the filter high end notch to fall so that everything **above 81 MHz** (70 + 11 which is half of 22) **falls down** into a valley. HN will not be a 'knife' chopping everything above 81 down; rather it will be more like a hill gradually rolling down. This means that you will actually adjust HN so that it is centered two or three MHz above the upper frequency limit of your chose passband (i.e. 83-4 MHz in our 22 MHz wide example). It will 'center' above the top of the desired passband but because it is a rather 'broad' notch trap it will start 'destroying' the flat passband down in the 81 MHz region. The same approach will be used for the LN trap; determine where you want to start rolling off the passband and set it two or three MHz **below that point**.

You may notice that after you have rough-aligned the HN and LN traps that you cannot get rid of variations greater than the desired + / - 0.5 dB within a few MHz of the traps but inside of the passband. Don't panic; go back and carefully re-align by touching up (only!) the LP and HP coils. Finally touch up the MP coil and then leave well enough alone. Note where on the scope display your passband flat portion (covering your chosen bandwidth) falls and mark it with a grease pencil. Now take the filter out of the circuit and connect the sweep output directly to the detector input. **Using the sweep output level adjustments** carefully bring the sweep-to-detector display down to where it coincides exactly with the grease pencil line made when the **filter was in** the circuit. The number of dB (or parts of dB) you had to take **out** of the sweep output to get the two lines to coincide is the **through loss of your filter**. Hopefully it will not be (much) more than 1.0 dB.

Note: If you do find that your swept flatness is greater than a dB or if the alignment is 'difficult' (erratic) or impossible, go back and check and re-check the wiring and physical alignment of the filter components. This type of difficulty indicates you have a **construction error** of some sort and no amount of alignment 'patience' is going to correct for that error.

The Demodulator Board

At this point we have a well shaped, amplified, 70 MHz (IF center frequency) FM signal at a level in the 10 to 200 millivolt region. Now we have to amplify it (again) and then detect it; turning it into a baseband signal that has video and subcarrier audio (or other modulation) present. We do our detection in a phase locked loop (PLL) and then we de-emphasize the baseband video signal, pass the video through low pass filtering and then amplifying the resulting video to a desired NTSC level for application to our RF re-modulator.

Circuit illustration and parts list are found in diagrams I and J while the top and bottom photos are found in diagrams K and L.

In this same circuit board we also have outputs that have the audio subcarriers, a DC voltage that is proportional to the strength of the 70 MHz IF signal and an automatic frequency control voltage centered at about 2 volts DC.

The PLL must have a certain voltage range of RF input for it to recover the modulation properly. The PLL is a form of 'active' detector and it functions in a manner unconventional to passive discriminators. Because of the unique 'electronic discriminator' approach of a PLL design there are certain operational advantages with the PLL for the backyard terminal builder. The primary advantage is sensitivity; PLL detectors have the ability to produce pictures with fewer 'sparklies' (noise impulses) than the conventional passive discriminator.

Satellite video is 'treated' at the uplink station so that certain parts of the waveform are 'increased' or emphasized. This 'electronic enhancement' is for transmission efficiency purposes and if the video signal from the detector was applied **directly to** a video monitor or modulator straight out of the detector this 'enhancement' would cause the picture to look 'out of balance'. The de-emphasis circuit puts the video bandpass signal back into 'balance'.

HOWARD [COLEMAN] DEMOD BOARD

Capacitors

13	.01 50 volt disc ceramic
1	470 MFD 25 volt electrolytic
2	100 MFD 16 volt electrolytic
2	22 MFD 35 volt electrolytic
3	4.7 MFD 35 volt electrolytic
1	4300 pF dipped mica
1	330 pF dipped mica
1	300 pF dipped mica
1	100 pF dipped mica
1	91 pF dipped mica
2	3 pF dipped mica
1	2-8 pF ceramic trimmer (Sprague QT1-11 - Radio Shack or equivalent)

Resistors (all 1/4 watt)

4	100 K
1	27 K
5	10 K
1	8.2 K
2	4.7 K
1	2.2K
1	1.2 K
3	1K
2	560 ohm
1	510 ohm
1	470 ohm
1	390 ohm
1	330 ohm
1	300 ohm
1	270 ohm
4	150 ohm
1	41 ohm
1	10K ohm pot (Radio Shack 271-218)

Inductors (all molded RFC type)

1	100 uHy
1	4.7 uHy
1	2.7 uHy

Integrated Circuits

1	NE 592N (Signetics)
1	NE 564N (Signetics)
1	MWA 120 (Motorola)
1	7812 voltage regulator, TO 220 case
1	7815 voltage regulator, TO 220 case

Transistors

3	2N2222

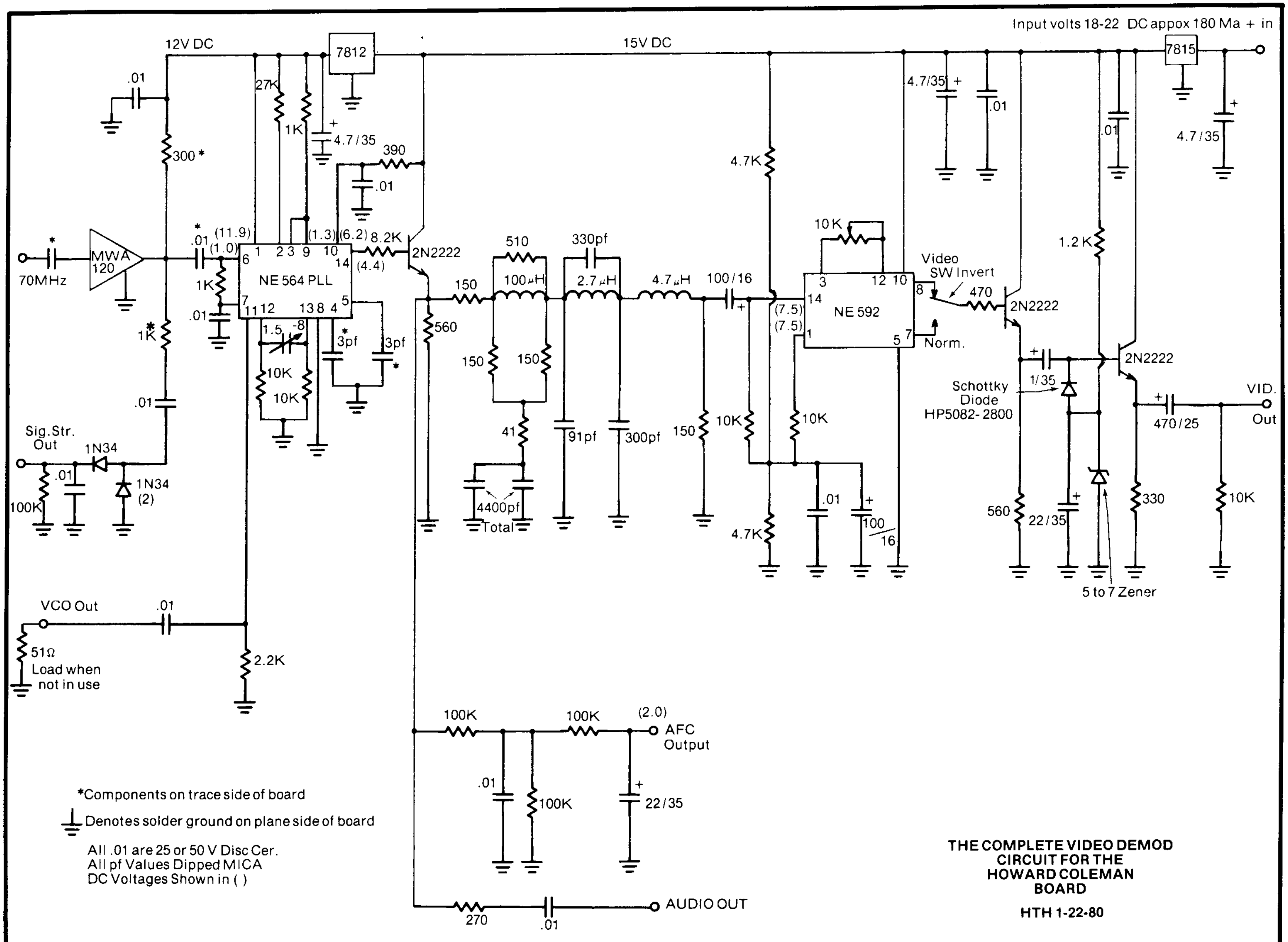
Diodes

2	1N34 or 1N38 or other small signal germanium
1	5082-2800 (Hewlett Packard)
1	5 to 7 volt zener, 1/4 watt

Figure J

The satellite audio is sent along with the FM video as an (FM) subcarrier. This audio subcarrier is transmitted typically at 6.2 MHz (Westar) or 6.8 MHz (most SATCOM transponders); although it may be on any subcarrier 'frequency' between 5.4 and 8.0 MHz. Once the video signal has been detected (at 70 MHz) to baseband the **video information components** are typically between 0.1 MHz and approximately 4 MHz. The detected signal then has the video you want for video display or remodulation, plus, it has the audio subcarrier(s). The audio is separated away from the video by a simple filtering network: everything **above** approximately 4.5 MHz is routed into the audio section of the receiver while everything **below** approximately 4 MHz is sent

(Text continues Page 23)



*Components on trace side of board

Denotes solder ground on plane side of board

All .01 are 25 or 50 V Disc Cer.
All pf Values Dipped MICA
DC Voltages Shown in ( )

THE COMPLETE VIDEO DEMOD CIRCUIT FOR THE HOWARD COLEMAN BOARD

HTH 1-22-80

FIGURE "I"

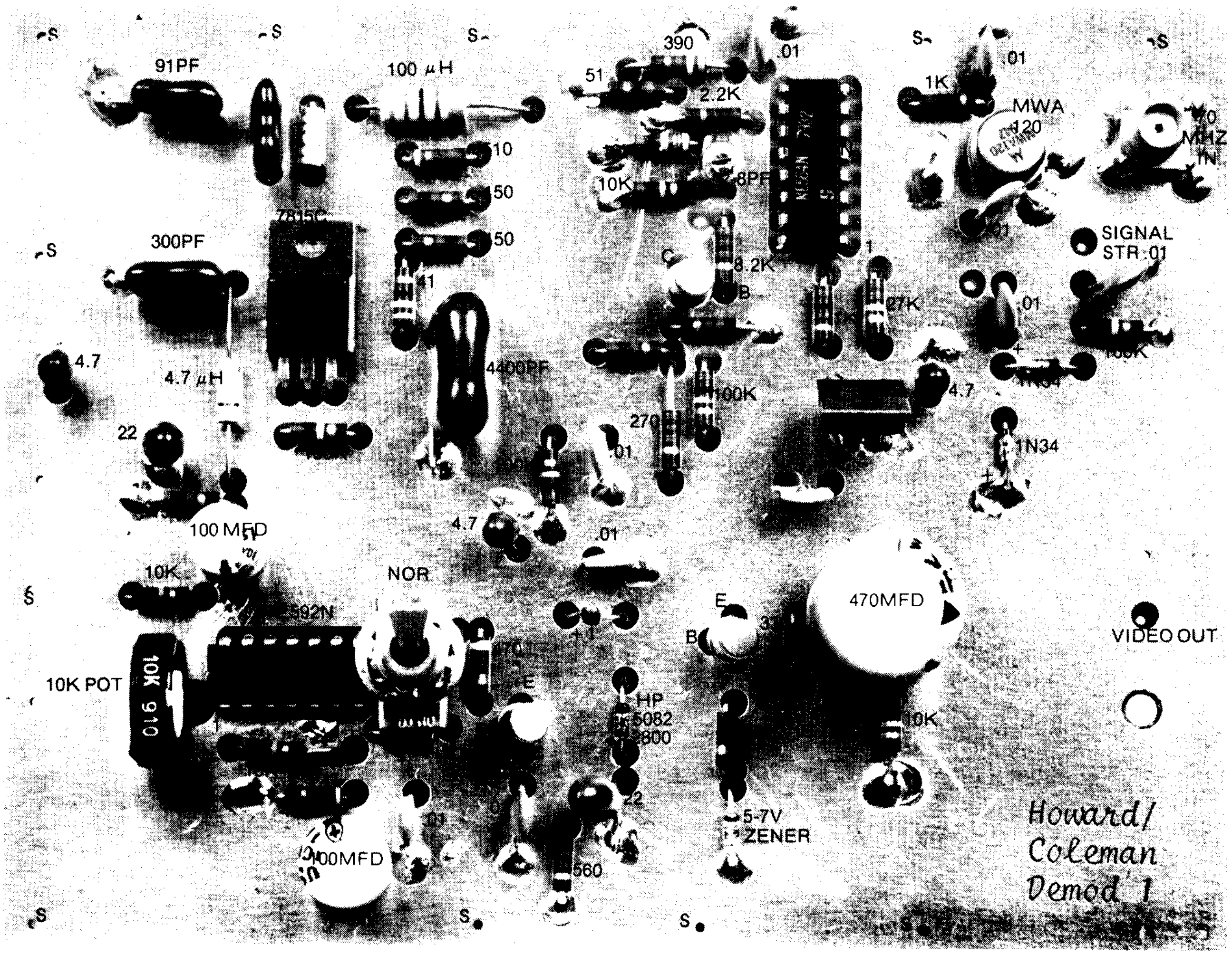


Figure K

HOWARD TERMINAL PARTS SOURCES

Most of the parts called for in this Manual are available locally, either through your local parts house or even at Radio Shack. Special parts, those that may require 'buying out of town', are spelled out in the parts listing. To locate those parts use this list.

Mixers
VARIL Corp. (3883 Monaco Parkway, Denver, CO 80207)
Engelmann Microwave (Skyline Drive, Montville, N.J. 07045)

Coil Forms
Quement Electronics (*), P. O. Box 6000, San Jose, CA 95150
*Miller coil forms widely distributed and stocked

VTOs
Avantek (Cain White Co., 105 Fremont Av., Los Altos, CA 94022)

Miscellaneous
Triko Caps (Stettner Trush, Inc., Cazenovia, NY)

Circuit Board Sets and miscellaneous parts
Robert M. Coleman, Rt. 3, Box 58A, Travelers Rest, SC 29690 (write for catalog sheets)

Standard Parts
James Electronics, 1355 Shoreway, Belmont, CA 94022 (write for catalog)

STANDARD
TRANSPONDER
ALIGNMENTS

Channel Number	12 Channel Bird - Center Frequency	24 Channel Bird - Center Frequency	Polarization Sense
1	**3720 MHz**		**horizontal**
		3720 MHz	vertical
2	**3760 MHz**		**horizontal**
		3740 MHz	horizontal
3	**3800 MHz**		**horizontal**
		3760 MHz	vertical

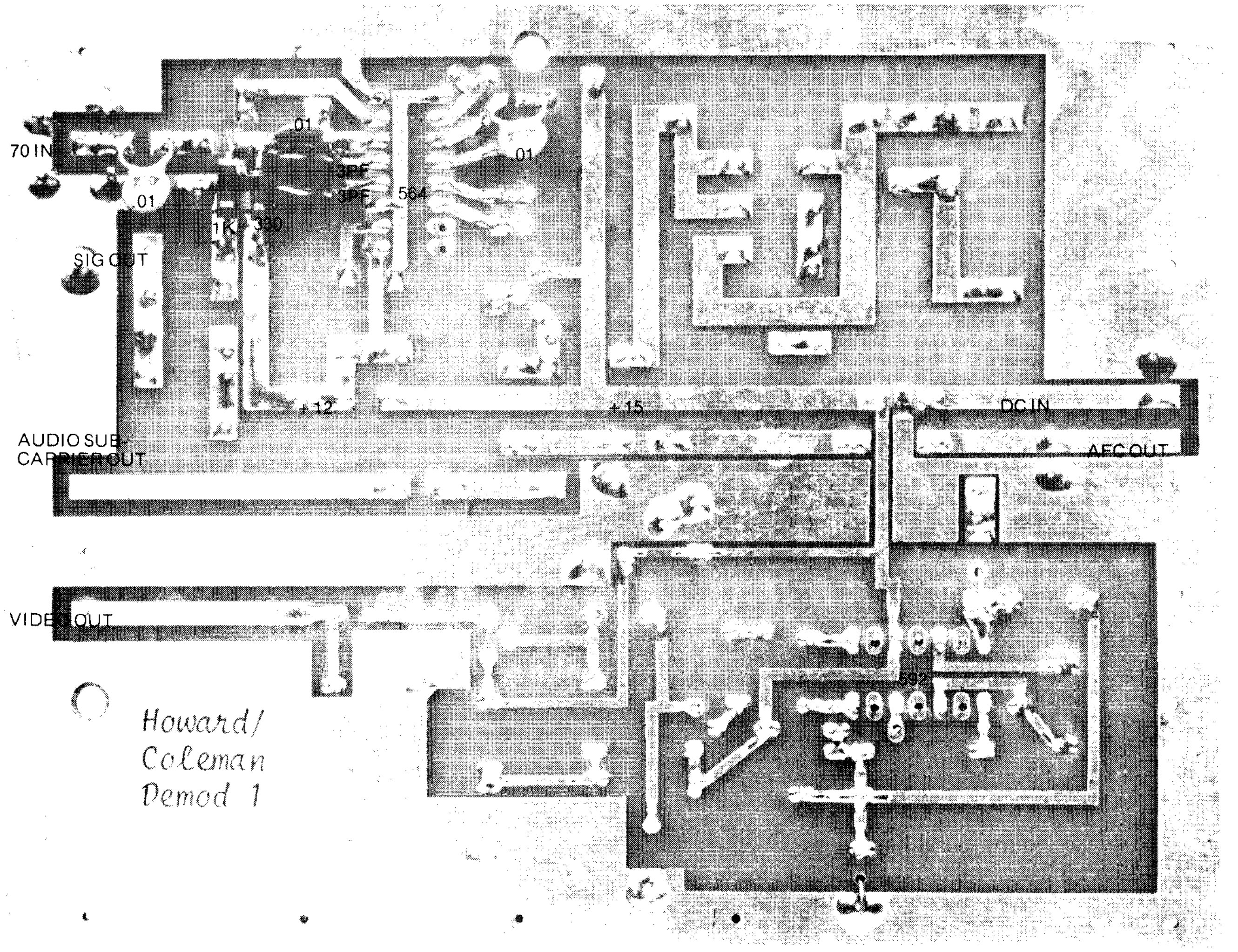


Figure L

4	**3840 MHz**		**horizontal**
		3780 MHz	horizontal
5	**3880 MHz**		**horizontal**
		3800 MHz	vertical
6	**3920 MHz**		**horizontal**
		3820 MHz	horizontal
7	**3960 MHz**		**horizontal**
		3840 MHz	vertical
8	**4000 MHz**		**horizontal**
		3860 MHz	horizontal
9	**4040 MHz**		**horizontal**
		3880 MHz	vertical
10	**4080 MHz**		**horizontal**
		3900 MHz	horizontal
11	**4120 MHz**	**horizontal**	
		3920 MHz	vertical
12	**4160 MHz**		**horizontal**
		3940 MHz	horizontal
13		3960 MHz	vertical
14		3980 MHz	horizontal
15		4000 MHz	vertical
16		4020 MHz	horizontal
17		4040 MHz	vertical
18		4060 MHz	horizontal
19		4080 MHz	vertical
20		4100 MHz	horizontal
21		4120 MHz	vertical
22		4140 MHz	horizontal
23		4160 MHz	vertical
24		4180 MHz	horizontal

Text Continues

on to the final video stages.

Prepare the circuit board by drilling all mounting and connector holes. Insert short pieces of wire through each of the holes marked 'S' on the figure and solder them on both sides of the board. Install the parts as shown. Be sure the MWA 120 is firmly seated on the PC board and that its mounting tab is soldered to the ground plane of the board.

With voltage applied to the board the total current drain should be around 180 mA. Check voltages per the values given on the circuit diagram. The only really critical voltage is on pins 3 and 9 of the PLL. **No two PLL devices are precisely alike** but the voltage 'window' should be between 1.0 and 1.5 volts. You can adjust the voltage to within this 'range' by **slightly** changing the value of the 390 ohm resistor going to pin 10 of the PLL. You set the trimmer capacitor on the NE 564 to produce a 70 MHz signal at pin 11 of the PLL; this should be accurate to within a couple of hundred kHz (i.e. the counter should read between 69.8 and 70.2 MHz). A second way of doing this adjustment is to lock the PLL to a 70 MHz signal generator signal (monitor in a receiver or compare the two signals on a scope) and then tune the trimmer capacitor to give an AFC voltage of 2.0 volts. Final tuning can be done with the TVRO receiver up and running (i.e. tune for best looking picture!). The input level to the demodulator for best operation is between 100 and 500 millivolts (RF) at 70 MHz. For reference the signal strength meter reads approximately mid-scale at 100 millivolts.

Single and Dual Audio Cards

The circuit diagram and parts list are diagrams M and N. The layout photo is diagram 0.

The audio cards accept the 5.0 to 8.0 MHz subcarrier frequency(ies) from the PLL demodulator and low pass filter. A bandpass filter separates the video and audio and the audio is demodulated using a standard TV (FM) demodulator chip. There are two audio outputs from each board; a 600 ohm line output intended to drive an amplifier or a TV remodulator, and, a low impedance output for driving a loud speaker with up to two watts of audio power. The single audio cards each have their own LM 380 audio amplifier to drive the speaker while the dual (i.e. two channel) audio card has a single amplifier. There are two gain controls; one is a 50K pot on the card for setting the line output level and drive to the amplifier, while the second is a 5K pot for setting loud speaker level. The 5K pot could be a trim pot on the card or a front panel mounted pot could be substituted for local operator control.

The audio amplifer is included in the circuit because it has been the experience of the author that you often take a TVRO receiver out to the dish proper (your dish or a friend's) and it is not always possible to haul along a RF modulator and/or monitor to the site. By having audio present, you can use the signal level meter to do antenna peaking and tests and the audio to verify which transponders you are tuned to.

Assembly of the card consists of merely inserting the parts according to the illustration and soldering them into place. **This note:** the current version of audio boards being produced differ slightly in parts location from the unit photographed. The 4.7 MFD capacitor is located right next to the number '9' at the top of the 9052 coil and the 1000 ohm emitter resistor goes off to the left of the capacitor. The ground end goes into a through-board hole.

The dual audio card duplicates the bandpass filter and detector section so that two frequencies (such as 6.2 **and** 6.8 MHz) can be detected and used independently from the single

HOWARD [COLEMAN] DUAL/SINGLE AUDIO

Dual	Single	Capacitors
2	1	3 pF dipped mica
2	1	12 pF dipped mica
2	1	50 pF dipped mica
2	1	68 pF dipped mica
4	2	91 pF dipped mica
3	3	.001 ceramic
6	3	.01 ceramic
2	1	.047 MFD ceramic
2	1	.47 MFD mylar or electrolytic
4	2	1 MFD electrolytic (10 volts or more)
4	3	4.7 MFD electrolytic, 35 volts
1	1	470 MFD electrolytic, 25 volts
		Resistors
2	1	220 K, 1/4 watt
2	1	150 K, 1/4 watt
2	1	6.8K, 1/4 watt
2	1	3.3 K, 1/4 watt
2	1	2.2K, 1/4 watt
4	2	1 K, 1/4 watt
2	1	10 ohm, 1/4 watt
2	1	50K pot
	1	5 K pot

NOTE: Use 1 pot on front panel and switch between 3065 outputs

		ICs and Transistors
2	1	CA 3065 (RCA)
1	1	LM 380 (National)
1	1	7812C voltage regulator in TO 220 case
6	3	2N2222
		Inductors
4	2	Miller 9051
2	1	Miller 9052

Figure N

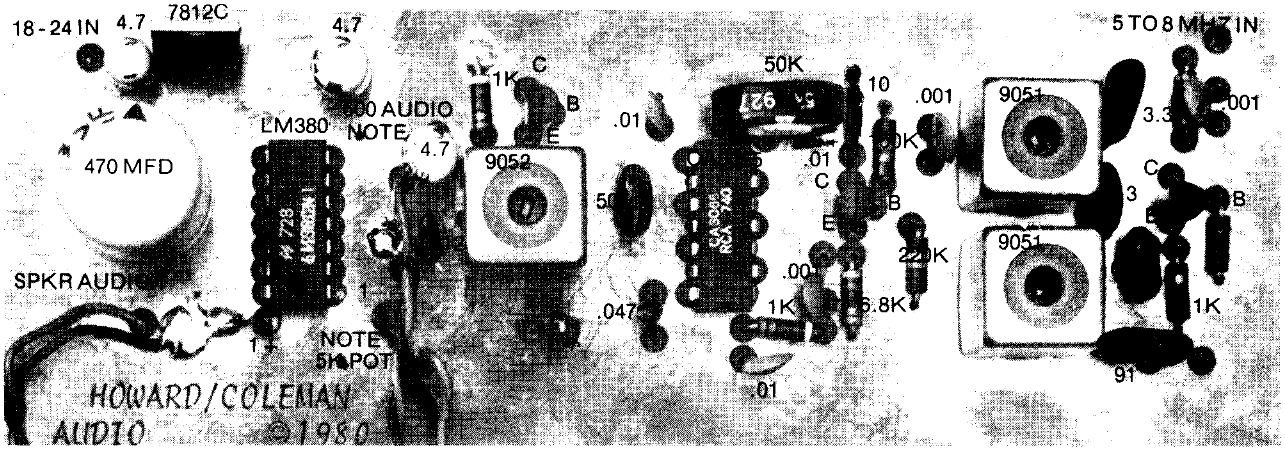
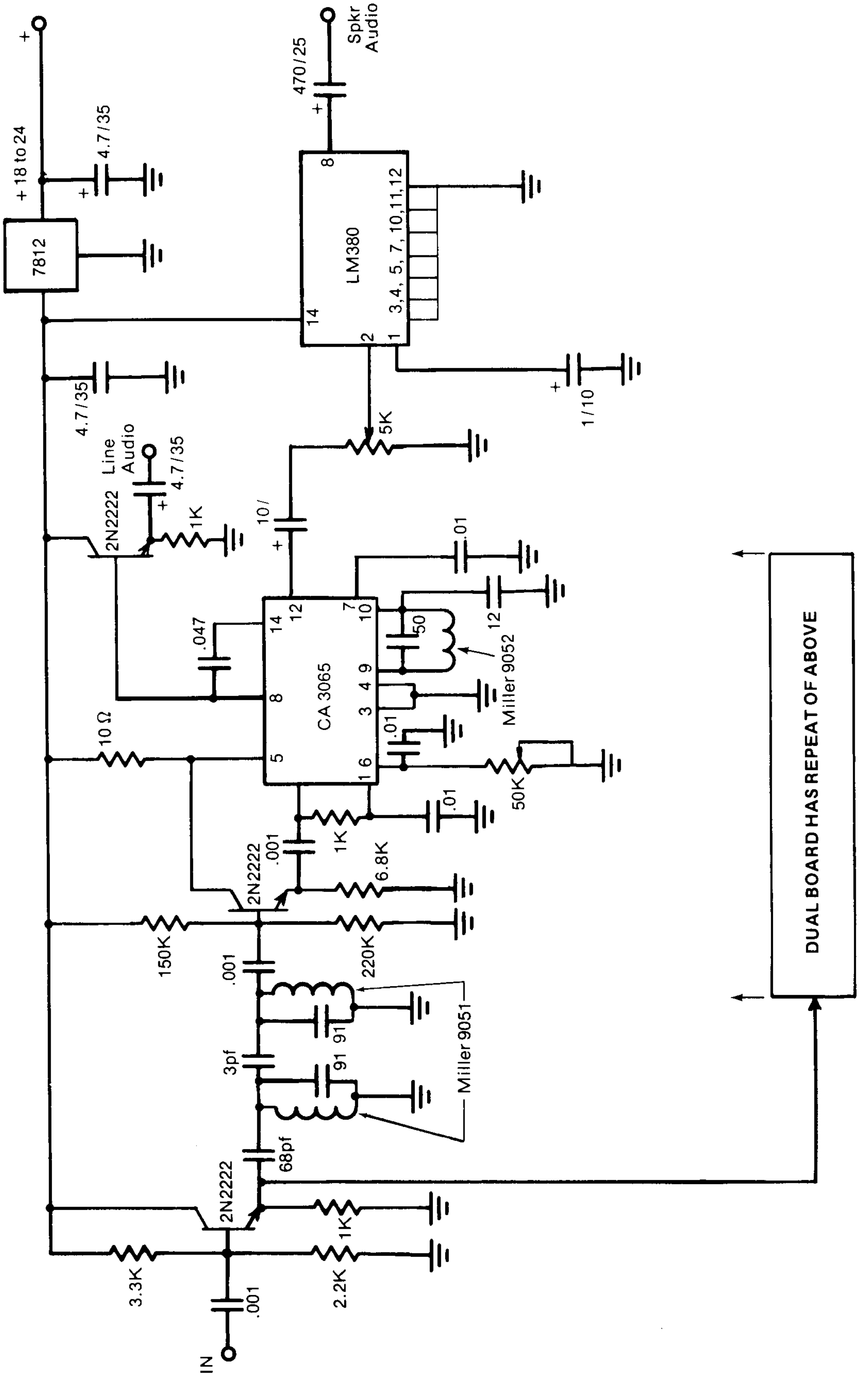


FIGURE "O"

Figure O



HTH 1-23-80

FIGURE "M"

card. With a front panel switch and volume control it is possible to switch the speaker amplifier between detectors for local monitoring of either subcarrier.

There are two ways to align the audio detector. You can do it by ear, without test equipment, if you have a few minutes to spare and are not uncomfortable adjusting the slug tuned forms (Miller 9051/2). The pair of **9051 coil forms** connecting to the base of the second 2N2222 form a tuned circuit which you must place **on the frequency** of the audio subcarrier to be detected. The 9052 form selects the same frequency for the CA 3065 IC demodulator. Set the 9051 forms to approximately mid-range and then with an audio system connected to the output and a TVRO signal flowing into the audio card from the PLL carefully tune the 9052 for **any** sign of audio. Peak it for maximum 'volume' and then go back and work the two input 9051 forms alternately, one against the other, until the audio is clean and crisp. **Note:** if you are setting the audio in this manner on a transponder with two (or more) audio subcarriers operating you may find that the audio you end up detecting is not the one that goes with the video. In this case you'll have to go fishing again to find the correct audio. By selecting audio on transponders 1, 5, 7, 8, 11, 16, 20, 22, 23 or 24 on SATCOM FI you will usually only have a **single** audio subcarrier present and will not be fooled. The higher technology approach is to use a signal generator producing a carrier on either 6.2 or 6.8 MHz. Connect the generator to pin 3 of the CA 3065 and place a wideband scope on pin 9. Tune the 9051 and 9052 forms for maximum indicated display on the scope (backing down on the signal generator output as you get closer to the tuned frequency). After getting the adjustable forms into the 'ballpark' in this manner you can make final adjustments on the discriminator adjustment (the 9052) by using your ear to detect the best quality audio.

The dual audio card duplicates the bandpass filter and detector sections so that two subcarrier frequency channels can be detected and used independently from the one card. With a front panel switch and volume control you can select both **which of the two audios** goes to the RF modulator and/or to the local speaker system.

DC Control And Metering Card

The circuit diagram and parts list are found in illustrations P and Q; the layout of the card is seen in illustration R.

The DC card performs the automatic frequency control, VTO tuning and metering functions. Insert the parts into the board per illustration R and solder them into place. Note there are 8 holes marked 'S' which need a short length of wire inserted through them; solder both sides of the board. The inputs and outputs of the board are labeled with letters corresponding to the circuit diagram. The pots set various receiver functions as follows:

HOWARD [COLEMAN] DC CONTROL BOARD

Capacitors

2	470 MFD 25 volt electrolytic
2	4.7 MFD 35 volt electrolytic

Resistors

1	1 megohm, 1/4 watt
3	10K, 1/4 watt
1	3.3K, 1/4 watt
3	2.2K, 1/4 watt
1	1K, 1/4 watt
2	5K 10 turn trimpots (Helitrim 89PR20K or equivalent)
4	20K 10 turn trimpots (Helitrim 89PRSK or equivalent)
1	10K 10 turn pot with counter

Integrated Circuits

1	7815C voltage regulator, in TO 220 case
1	LM 324

Switches

1	5 pole rotary
1	SPDT
1	DPDT

Meter

1	0-1 ma

Power Supply

1	18 to 24 volt DC at 1 amp, regulated

Figure Q

1) **R1** sets the VTO 8090 frequency. **Measure** the VTO voltage and set it initially to about 2.4 volts.
2) **R2** sets the range of the receiver meter for measuring the 8240 VTO voltage. With the receiver showing first signs of life find transponder 24 and set this pot so that **full scale** on the meter corresponds to transponder 24. All other transponders will then read 'down scale' and you can work out your own "voltage corresonds to XXX transponder" chart.
3) **R3** sets the meter range for reading the VTO 8090 voltage. R3 can be set to read direct voltage (0-10 volt scale).
4) **R4** sets the meter scale for reading AFC voltage. This is adjusted by turning the AFC 'on', tuning in a picture for

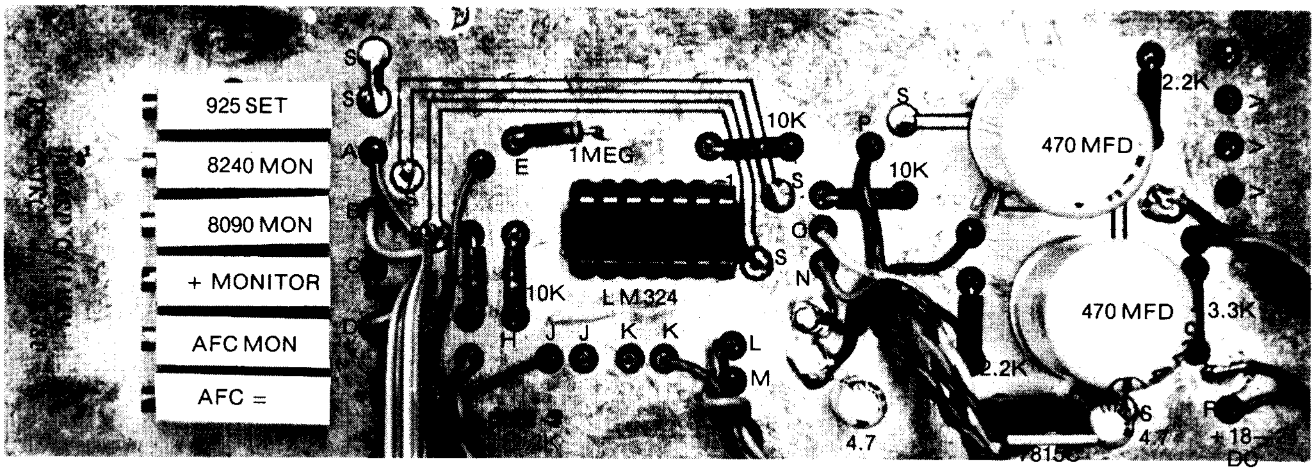
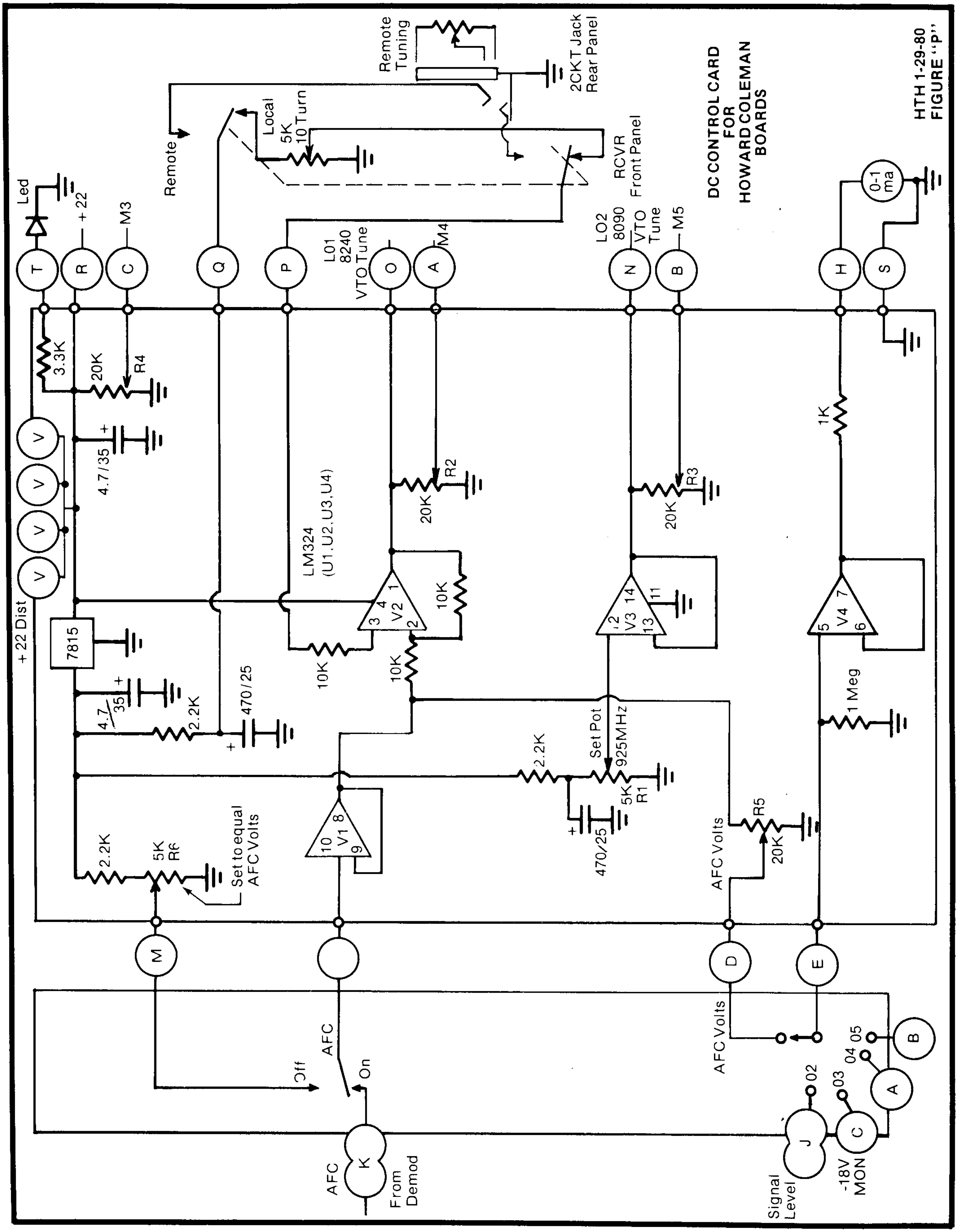


Figure R



DC CONTROL CARD FOR HOWARD COLEMAN BOARDS

HTH 1-29-80 FIGURE "P"

best visual quality, and then setting R4 so that it reads mid-scale. On the 0-1 volt scale mid-scale is .5 volts.

5) **R5** is set **after** R4 has been adjusted by turning the AFC 'off' and setting this pot to give a mid-scale indication when the picture is perfect. When you have this pot set properly it is possible to flip between AFC on and AFC off and see no change in picture quality. If you tune in a picture slightly off-center (i.e. to one side) with the AFC **off**, by flipping the **AFC on** the picture should snap into 'center-tune'.

This designer note: These pots work anti-clockwise; that is, clockwise **decreases** the voltage. This is not the normal fashion for pots to be wired but since you only set these adjustments once per receiver the backwards pots were wired in this fashion to facilitate the layout of the board.

The final tune up needed is to set the four Triko trimmers on the down converter board. This is done by tuning in a signal with the AFC 'off' and broadly peaking the trimmers by 'bracketing' the point where the signal falls off. Go through the adjustment 2 or 3 times. Turn the AFC back 'on'; if the signal 'goes away' (i.e. the AFC detunes the VTO) you have set the capacitors too far 'out' (high side IF). Turn the AFC off and find the low side peak, typically 'in' a couple of turns.

Remodulating to RF

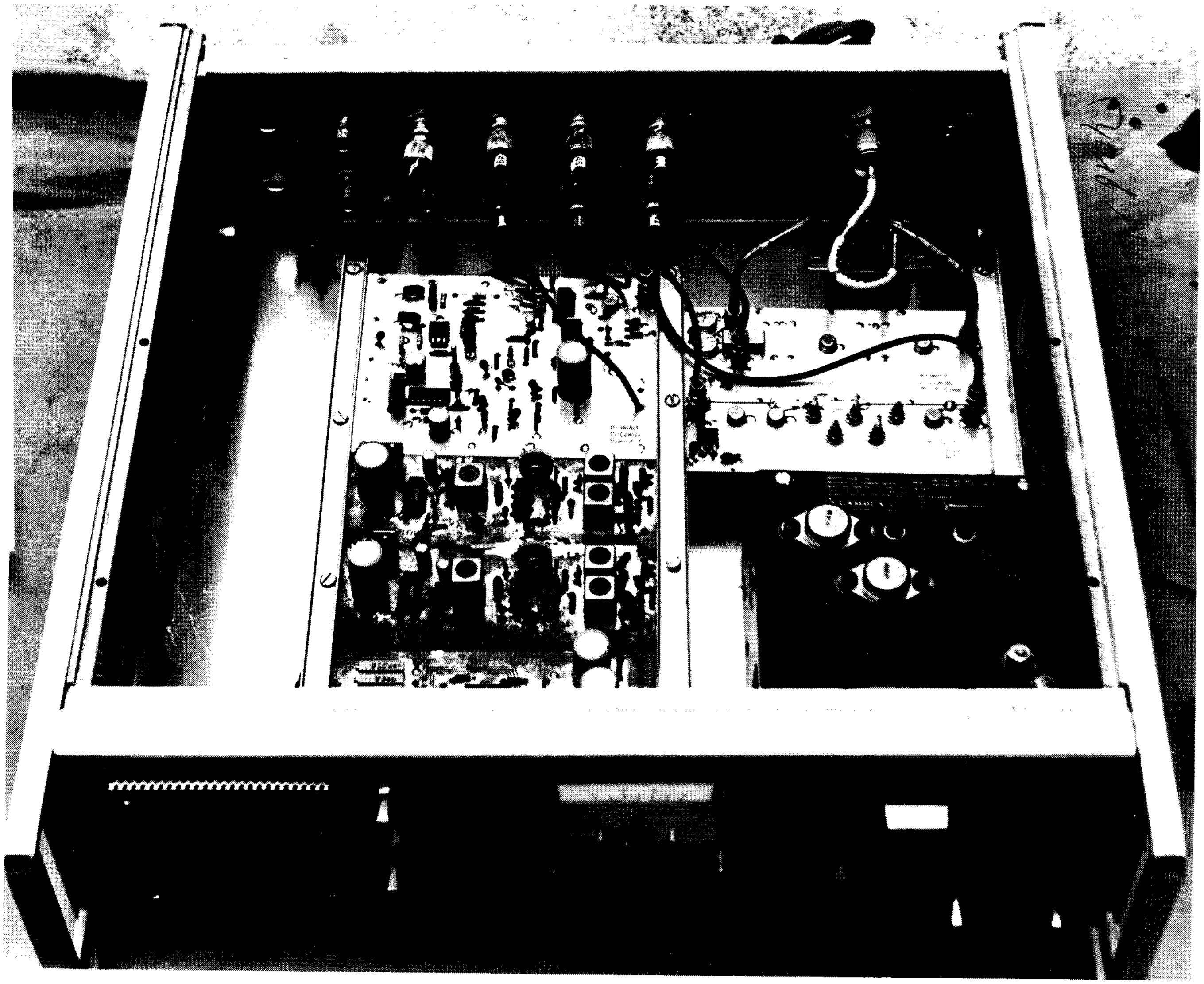
The original Howard Terminal receiver included an RF remodulator.

The premise for remodulation is straight forward. The satellite downlink signal is **not** compatible with your standard TV set. Not only are the satellite frequencies not tuned by a standard TV receiver but they are FM (video) whereas the standard TV transmissions are AM.

The satellite receiver downconverts the SHF 3.7 to 4.2 GHz frequency band to a manageable 70 MHz (low) IF and then demodulates the FM signal to raw video and audio; **or baseband**. Once we have a pure video signal and a pure audio signal both can be connected to a simple RF modulator (or remodulator).

The video amplitude-modulates a low power carrier, typically on VHF channel 3 or 4. The audio rides along a 4.5 MHz aural-offset carrier. This is the format found in NTSC (US, Canadian, etc.) terrestrial television transmissions.

These low power RF remodulators are very commonly available; to the point that there is no longer any real need to discuss such a circuit in detail. Low cost kits are available (**ATV Research**, Dakota City, NB, **Ramsey Electronics**, 2575 Baird Rd., Penfield, NY 14526) but perhaps the 'easiest' approach to



PACKAGING EXAMPLE - One proto-type packaging version prepared by the author.

remodulation is to utilize your home VCR unit. Virtually every VCR on the market has an auxiliary input for external video and audio. Most BETA series machines route both the video and audio to the low power modulation within the machine and then by simply placing the VCR into the 'on' mode you have an RF carrier output (switch selectable on the VCR between channels 3 or 4) which will carry your satellite signal to your TV receiver.

Most VHS series machines do the same thing **except** some models 'block' the audio from feeding through the modulator **unless** there is a tape in the machine and the machine is in the record mode.

Wired and tested external RF remodulators are also available from '**Radio Shack**, P. O. Box 188, Petersburg, W.VA 26847'.

Plotting System Performance

Once your operating system is functional your mind may wander to the supreme question; 'How Well Does It Work?'. Of course the quality of your pictures tells you something about system performance but eyeball checks fail to give you assurance that you are getting the last 1/2 dB from the antenna/LNA/receiver.

One way to accomplish such a check is to use **the sun as a noise source**. The sun generates a known amount of flat (i.e. not frequency sensitive within the 3.7 to 4.2 GHz range) noise and because the sun is in the sky with the satellite(s) you can direct your antenna so that the sun will 'drift' through the fixed antenna position.

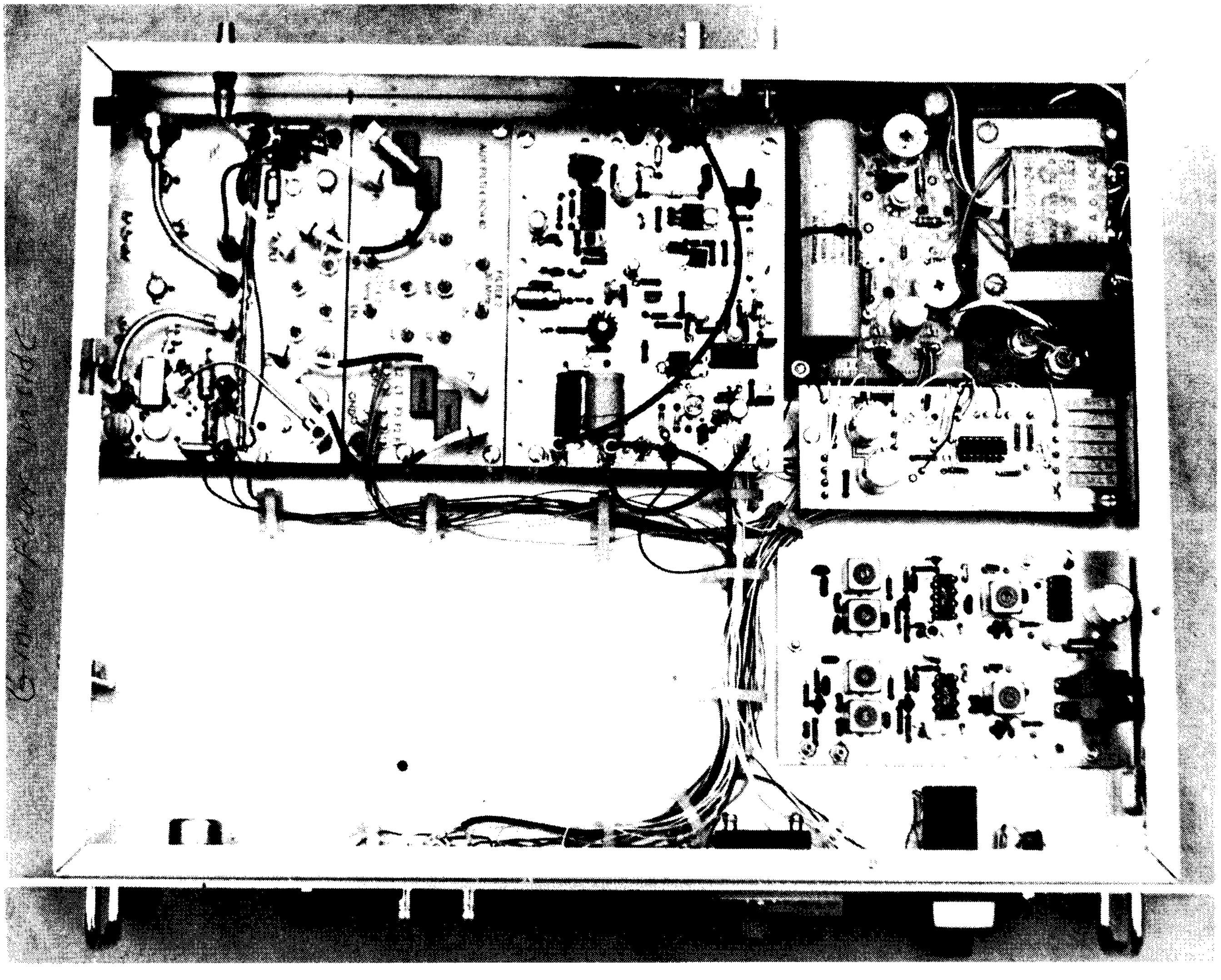
1)If your antenna has a prime focus feed (i.e. LNA and feed horn located at focus point as discussed previously in this Manual) adjust the antenna elevation and azimuth so that the sun places an LNA/feed **shadow** directly into the **center** of the dish. This tells you the dish is aligned to the sun.

2)Move the antenna **ahead of the sun** so that the sun will move through the dish, still with the sun placing LNA/feed shadow directly into the dish center.

3)Tap into the receiver's 70 MHz IF prior to any hard limiting that may take place in later IF amp stages (hard limiting is caused when the signal input voltage plus amplifier gain rises the output level to a **stable** condition).

4)**Meter** the 70 MHz IF signal level while the antenna is looking out into space **ahead of** the sun. As the sun drifts **through** the antenna (tracing a feed/LNA shadow across the dish) monitor and record the variation in signal (noise) level.

5)When the sun is precisely aligned with the dish (LNA/feed shadow in the exact center of the dish) use a **1 dB step attenuator** at the input to the receiver to back off the signal level on your 70 MHz IF metering point to the same metering point indicated when you were pointing



PACKAGING EXAMPLE - Howard Terminal Receiver built and packaged by California builder Lance Ginner.

into space ahead of the sun. **Note how many** dB of attenuation (using a 4 GHz capable attenuator) you had to 'crank in' to make the before and after readings identical.

Now you have to do some calculations. What we are going to compute is the receive system 'figure of merit' or "Gain" over "Temperature". The formula is:

$$G/T = 10 \log \frac{10 \log (\text{dB increase} - 1)}{-.130} \text{ dB per degree K}$$

The theoretical G/T for comparison is:

$$G/T = 10 \log \frac{\text{antenna gain}}{\text{system noise temp}} \text{ dB per degree K}$$

For example the G/T for a 15 foot antenna (43 dB gain = 20,000) with a 300 degree system temperature is:

$$G/T = 10 \log \frac{20{,}000}{300} = 18.24 \text{ dB per degree K}$$

For a system which sees (i.e. measures) an 11 dB increase in background noise when aimed at the sun, the actual G/T is:

$$G/T = 10 \log \frac{10 \log 11-1}{0.130} = 18.6 \text{ dB per degree K}$$

Assuming antenna gain of 20,000 (15 footer) one can use this to calculate a system noise temperature of 276 degrees K. For a complete explanation of this technique using the sun as a radio (signal) source see **Microwave Journal** for April 1977; volume 20/number 4, pages 49, 51, 58 for 'Satellite Earth Terminal G/T Measurements'.

There are warnings about purposefully pointing your **solid surface** TVRO antenna into the sun's path. The sun is not only a radio signal source, it is also a heat source. A solid metal reflector captures sunlight and if the antenna surace is not painted to break up the sun light you will focus the sun's rays back to the feedpoint; just as you do with the satellite signals. A twenty foot surface, unpainted, covered with dull aluminum, can create intense heat at the focal point. It is possible to raise the temperature of an object placed at that focus point by as much as 2,000 degrees F!

Therefore unless you have a non-solid surface or you have a solid surface with a good painted top coat such that the sun's rays do not collect and refocus, the author suggest you **not point into the sun**. Your LNA and cables could be permanently damaged or even destroyed by the intense heat that can be generated in this fashion.

Interestingly the sun will align with your TVRO antenna at least twice per year if you leave the antenna fixed on a satellite (such as FI). During the spring and fall equinox seasons the sun will cross over the equator and be (for about 20 minutes per day for two to four days) **directly behind the satellite** in the mid to late afternoon period. When this happens the sun's noise will be equal to or greater than your satellite signal at your terminal for approximately 6 to 8 minutes time and the noise from the sun will actually cover up (i.e. wipe out) any sign of satlelite signal for that brief period.

Finally, during solar cycle peaks and after for several years (one has just occurred) the sun's noise output varies as a function of sunpots present. It is possible for you to have a **noisy sun** on the day you make this test and this increase in solar noise level (as measured at your 70 MHz IF metering point and quantified with the 1 dB step attenuator) may cause you to **think** you have a far better G/T than you really do. If you have access to a shortwave receiver, check ESSA/NBS service WWN on 5, 10, 15 or 20 MHz at 18 minutes past the hour to see what the solar activity index is for the day.

In Conclusion

Well now, you have pictures from your system. So what is next? Most of us strive to improve the pictures, gain better control of signals from weaker (off boresight) satellites and generally upgrade the now working system. There are a few not too complicated areas where you can effectuate improved performance with a minimum of expense and time on your part.

1) **The feed horn** designed presented here is simple and it performs well. But you can gain from .5 to 1.5 dB of additional system signal (and therefore improved CNR) if you will look carefully at what the feedhorn does and how you can improve it. Unfortunately this may not be a do-it-yourself project since more complicated feed horns entail a fair amount of accuracy with precision milling or tooling. I do recommend you look into the Chaparral 'Super Feed' (**Chaparral Communications**, P. O. Box 832, Los Altos, CA 94022). Extensive testing indicates you may change your feed in this manner and gain the advantage of an antenna reflector surface up to 30% larger in size over the feed horn shown here.
2) **The receiver design** presented here has been kept as simple as possible. In this approach there is no receiver circuit that provides **input** filtering. It is assumed that the LNA will provide sufficient 3.7-4.2 GHz bandpassing to eliminate the need for a dedicated filter at the input to the receiver proper. Unfortunately not all LNAs are designed with this in mind; **some** of the commercial units available have been shown to produce substantial amounts of 'noise' at the receiver's image frequency. This noise flows into the receiver proper and causes a 'noise floor' which artifically limits the sensitivity of the receiving system. One good solution to this problem is offered by **International Crystal Manufacturing Co.** (ICM, 10 North Lee, Oklahoma City, OK 73102). It is called 'The Purifier' and it is a combination bandpass filter (3.7 to 4.2 GHz) and a single stage amplifier. You install The Purifier at the input to your receiver and it provides additional gain (important if you have a long, or lossy feed line) as well as rejection of noise or signals that are out of the desired band.
3) **The 564 PLL** is the limiting factor in video **quality** in the present receiver, due to it limited tracking range. However the cost versus performance trade offs make other demodulators poor choices for low cost private terminal receivers. Recently however a new approach wherein a divide by two detector scheme PLL has been developed. In this approach the 70 MHz IF signal is divided to one half frequency (35 MHz) and is then presented to the 564 PLL. This causes the PLL to operate in a lower frequency range, where tracking is considerably improved. This approach has been packaged by Microelectronics Technology Corporation of Palo Alto, CA and the package is available from ICM at the address given in (2) above and from Robert Coleman. While it does not plug directly into the Howard Coleman board it can be put on the board with about one hours work.
4) The marketplace is beginning to see competition for the first mixer. VARI-L now offers the 500 and 1100 models while several other firms are producing equivalents. The specifications given on page 13 are a good shopping guide. Ask the vendor if he has tried them in the Howard Terminal; if not, educate **him**.

A final personal note from the author.

In answering our correspondence over the past two years, I have found that most of the problems which crop up are "common" ones caused sometimes by my own lack of clarity or presumption of knowledge and other times by readers that are over their heads technically because of other motivations. The readers must realize that he or she is traveling a pioneering trail and that most questions are, in truth, contributions. I try to answer all my mail promptly (and usually within two weeks) and always answer those with self-addressed stamped envelopes or technical contributions first. Technical questions are usually relatively easy while those from "over the headers" I handle by suggesting sources for local help.

Legal questions regarding receipt and use of satellite signals have not all been answered or, for that matter, asked. The Society for Private And Commercial Earth stations (SPACE) is actively working on these problems and need your support. For an annual membership fee of $35 you will get a newsletter and up-to-date word of congressional action. The next two years will see strong legislation attentive to protecting individual rights and those of the programmers. Your membership and participation will help to protect those rights and, if negotiations now in progress conclude successfully, will guarantee your legal access to certain satellite programming.

Write: S.P.A.C.E.
1521 "O" Street NW
Washington, D.C. 20005
(202)387-1856

NOTES

NOTICE TO HOWARD MANUAL USERS:

While this Manual is intended to be a complete guide to construction of a (New) Howard Terminal Receiver system, there is no way that such a Manual can pre-guess every builder's questions nor his particular aptitude for such a project. For this reason the Manual's author, **H. T. Howard**, makes himself available for 'mail-order-consultation'. If you wish to seek advice on this system, its construction, or use, we suggest you "sign up" for the Howard By-Mail Consulting Service using the form below or simply by jotting the relevant data down on a piece of paper.

The fee to enclose (make check payable to H. T. Howard) is $25. This entitles you to **write** as long and as often as you wish asking for advice relative to this project. Sorry, no telephone consultations and if you wander off on your own attempting to substitute parts, circuit modifications or otherwise deviate from the plans presented here...you **are** on your own.

ATTENTION: Mr. Henry T. Howard / P. O. Box 6401, Stanford, CA 94305

I wish to sign up for your 'letter advisory/consulting service' and to be able to write for advice, assistance or additional information. I understand this assistance is limited to those who follow the published plans precisely and does **not** extend to circuit modifications or parts substitutions not discussed in the text. My check / money order (for $25) is enclosed.

NAME ______________________________

Mailing Address ______________________________

Town/City ______________ State ______________ Zip ______________

I further understand that this consulting / advisory service extends only to myself as the original purchaser of this Manual and does **not** extend to others who may 'share' the manual.

For Howard Use: Date accepted - ______________________________

File Number - ______________________________

Letter History - ______________________________

NOTES

TAYLOR HOWARD MAN-OF-THE-YEAR!

COOP'S SATELLITE DIGEST

JANUARY 1981